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Technical Training Manual

Understanding Scan Tools

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- Understand active and passive monitoring
- Learn why you should use your scan tool on every single vehicle
- Confidently use live data to assist diagnosis
- Know where to find correct information

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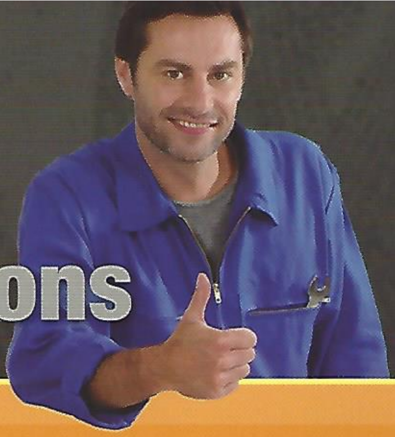

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SCAN TOOL OPERATION

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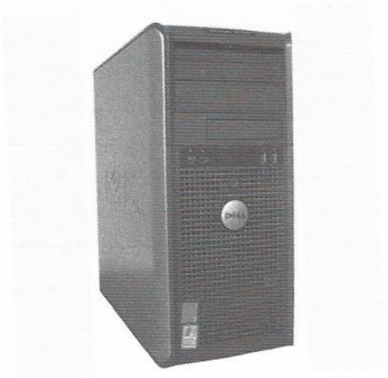
E. & O. E.

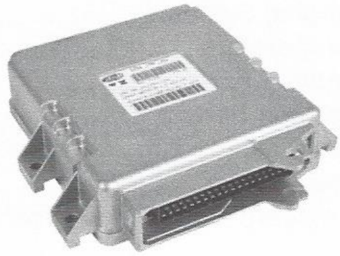
INTRODUCTION

A computer is made up of many components, including the Central Processing Unit, Pulsed Generator Time Clocks, memory chips to store information and software to run the programs. Input data is received into the Central Processing Unit (CPU). The CPU processes this information, stores the information and will transmit output signals once the information has been processed.

A computer screen shows what's happening inside the PC tower…

Just as a scan tool shows what's happening inside the ECU.





When we sit in front of our home computer and send data to the CPU via the key board, we read the output information on the screen in front of us. With computers in motor vehicles we cannot readily see the input or output information which makes it difficult to comprehend what is happening in the computer. That is where the scan tool comes in.

Scan tools are extensions of vehicle computers. They allow us to see and read input and output information on most late model vehicles. Scan tools are an important diagnostic tool. Becoming familiar with their operation will help in diagnosing engine management system malfunctions.

Types of Scan Tools

There are two different types of scan tools:

- Genuine (those developed by vehicle manufacturers)
- After Market, even though in some cases they may both be produced by the same scan tool manufacturer.

GM's Tech II, Ford's WDS and Nissan Consult are examples of dedicated Scan Tools hardware.

Tech II

Ford WDS

Nissan Consult

Genuine Scan Tools

Since the emergence of On Board Diagnostics, most vehicle manufacturers have developed their own dedicated scan tools (hardware) and the programs that operate them (the software). The cost of both parts of the equation (hardware and software) can be very expensive. In most cases neither are usually made available to the trade or public in Australia.

In order to reduce those costs and provide greater flexibility, many vehicle manufacturers are now moving away from dedicated hardware to generic hardware such as:

- Laptop computers
- Palm pilot (Pocket PC)
- Generic touch screen display tablets (screen).

This means that the cost of the hardware is now reduced due to the common nature of these devices. The remaining expense is for:

- Cables and adaptors from the tool to the vehicle
- Operating Software
- Software updates.

Note!

Some manufacturers recommend specific brands and models of generic hardware due to potential operational conflicts with their networks.

The cost of developing software to run diagnostics is very high and it needs to be continually updated for new model vehicles throughout each year. So there is an ongoing cost to the OE dealer for their genuine scan tool software updates. These may be via regular CD mailings (quarterly or more frequently if required) or via Internet updates.

After Market Scan Tools

The After Market scan tool manufacturers have always had to play catch-up and reverse engineer their software for the many different makes and models of vehicles that they try to service.

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F6

This means that their software may always be released some period of time after new model vehicles are released. There are similar trends emerging in the After Market scan tool industry, where some scan tool manufacturers are using similar generic hardware as the vehicle manufacturers.

Some After Market scan tools may be able to carry out programming and security functions like the factory scan tools. You need to explore all the capabilities of your scan tool to fully understand what it can and can't do.

Note!

If you are sometimes frustrated with bugs that may appear with After Market software updates, the Genuine software updates often have bugs of some kind also.

Take care with unknown scan tools as it is possible to cause damage to some modules.

New Generation Genuine Scan Tools

We are beginning to see Genuine scan tools that are not just scan tools but have many generic computer functions as well. Some manufacturers have already had these for a number of years.

These New Generation Genuine scan tools are being connected to the rest of the dealership via a Local Area Network (LAN) and to the world via the Internet.
The scan tool function is being expanded to provide live access to:

- Factory Technical Bulletins
- Workshop manuals
- Guided diagnostic procedures; either built into the scan tool software or accessed from the factory via the Internet.

These scan tools are able to communicate direct to the factory via the Internet (or in some cases via satellite). If the dealer is having trouble diagnosing a vehicle concern, the tool can send the self test data back to the factory where technical staff can assist in the diagnosis.

Another process is the updating of Calibration software within the PCM. The scan tool can communicate the Vehicle Identification Number (VIN) back to the factory and it will advise if software upgrades are available. If so, these will be readily downloaded via the scan tool into the PCM (reflashed), keeping it up to date and enabling the vehicle to behave better than when the customer dropped it off.

G-scan
HYUNDAI
ESC
view MENU
view applications
view functions
view OBDII / DATA
view search
view memo mode
view features

The picture above shows the genuine Hyundai (and Kia) factory Scan tool

Hyundai (and Kia) have adopted the G-scan as their genuine factory scan tool for use in dealerships. Be aware that although the G-scan (or other similar generic scan tools) may be available to the aftermarket, only the genuine scan tools are programmed to have full security access for functions such as key training and PCM reflashing.

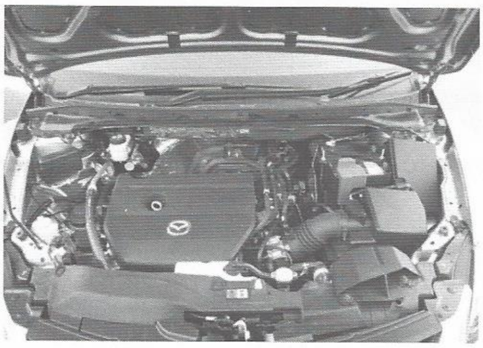
Modern Vehicle On Board Diagnostics

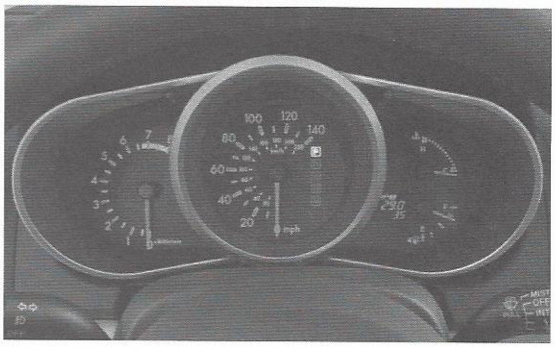
The complexity of Electronic Management Systems in motor vehicles continues to increase at dramatic rates. Advanced electronics control nearly every system on the modern motor vehicle. These systems are becoming more interlinked by the use of Controller Area Network (CAN) systems. There are a number of key, yet conflicting drivers of this change. Vehicle manufacturers are trying hard to reduce manufacturing costs and assembly complexity. Customers require greater functionality and creature comforts from their vehicles, but at reduced purchase and maintenance costs. The other main player is the increasing legislative requirements for reduction of motor vehicle emissions.

The thing about emission requirements is that they are always changing and the rate of change is always increasing. The reason that we bring this up is that this is what is driving many of the diagnostic processes that you will be involved with in repairing modern engines. With only normal servicing, these vehicles are now required to maintain low levels of emissions for up to 100,000 kilometres or 5 years of ownership. While these changes are happening involving the manufacturers and government bodies, the independent technician MUST find ways to keep up with these technological advancements. The days of just extracting codes with LED lamps and multimeters is fast disappearing. Nevertheless, the concepts they involve are fundamental in all that we do today.

Scan Tools are the new starting point. Vehicle manufacturer's scan tools are generally not available to the trade. Some can be sourced overseas on the Internet, but the missing link will be the ongoing software changes for local models.
This software is in two forms:

1. Ongoing updates to conduct tests on new model vehicles and systems as they are released.
2. To "reflash" a PCM with a revised program to overcome problems as they emerge in the field.





Some manufacturers have revised software for some of their vehicles almost from month to month. Only factory dealers have access to these upgrades. After market scan tools are always playing catch up to work on current vehicles. Functions such as training new keys and replacement odometer setting will tend to be only accessible by some scan tools & factory dealers.

Factory Technical Service Bulletins (TSB) are usually only available to dealers. In countries like the US, independent technicians can subscribe and access manufacturer web sites to gain service manual and factory Technical Service Bulletin information. These services are gaining popularity in Australia. The time may come when the independent technician will need to have an allegiance with their local factory dealers to obtain some of these services for their customer's vehicles.

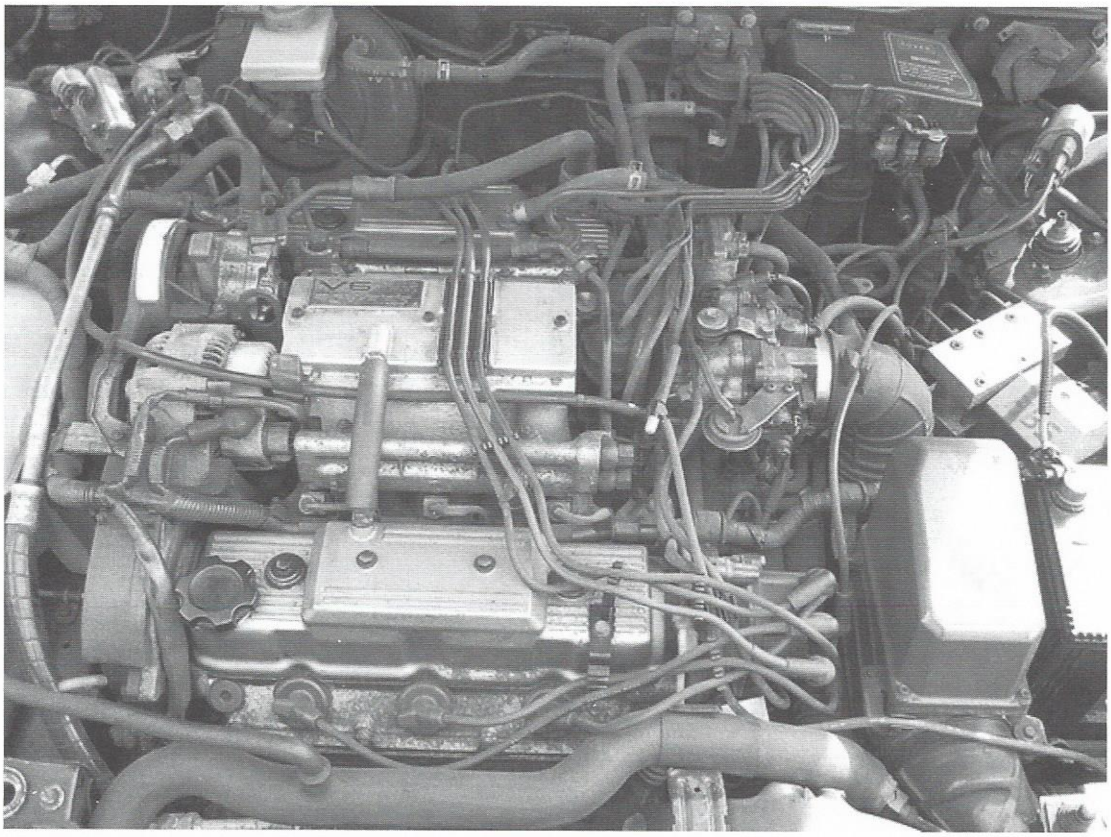
This Training Manual will look briefly at how the latest emission requirements and subsequent On-Board Diagnostics standards have led to more diagnostic information being available to today's technician through the many different scan tool interfaces available. It will also explore some of the latest OBD compliant systems from the perspective of an Australian, an American and a Japanese built vehicle.

Emission Controls in Australia

The first time we came across the term "emissions", dates back to the early 1970's. Prior to that, not a lot had changed over many years. The first shock came with Australian Design Rule (ADR) 27a in 1976. The engines that we were very familiar with, all of a sudden were carrying extra components and sub systems, and didn't seem to run as well as they used to.

It also saw the phasing out of Kettering ignition (points) and the introduction of high energy ignition systems, exhaust air injection, EGR valves, intake air preheat, spark advance delay systems, retarded camshaft timing, idle control solenoids, manifold temperature control devices and so on. Vacuum hose manufacture was a new growth industry! There were many new things for the Technician to get a handle on. Unfortunately, many of these systems received the "ball bearing" or other forms of blocking treatment. Carbon canisters had already been around for a few years and had received a fair share of treatment already.

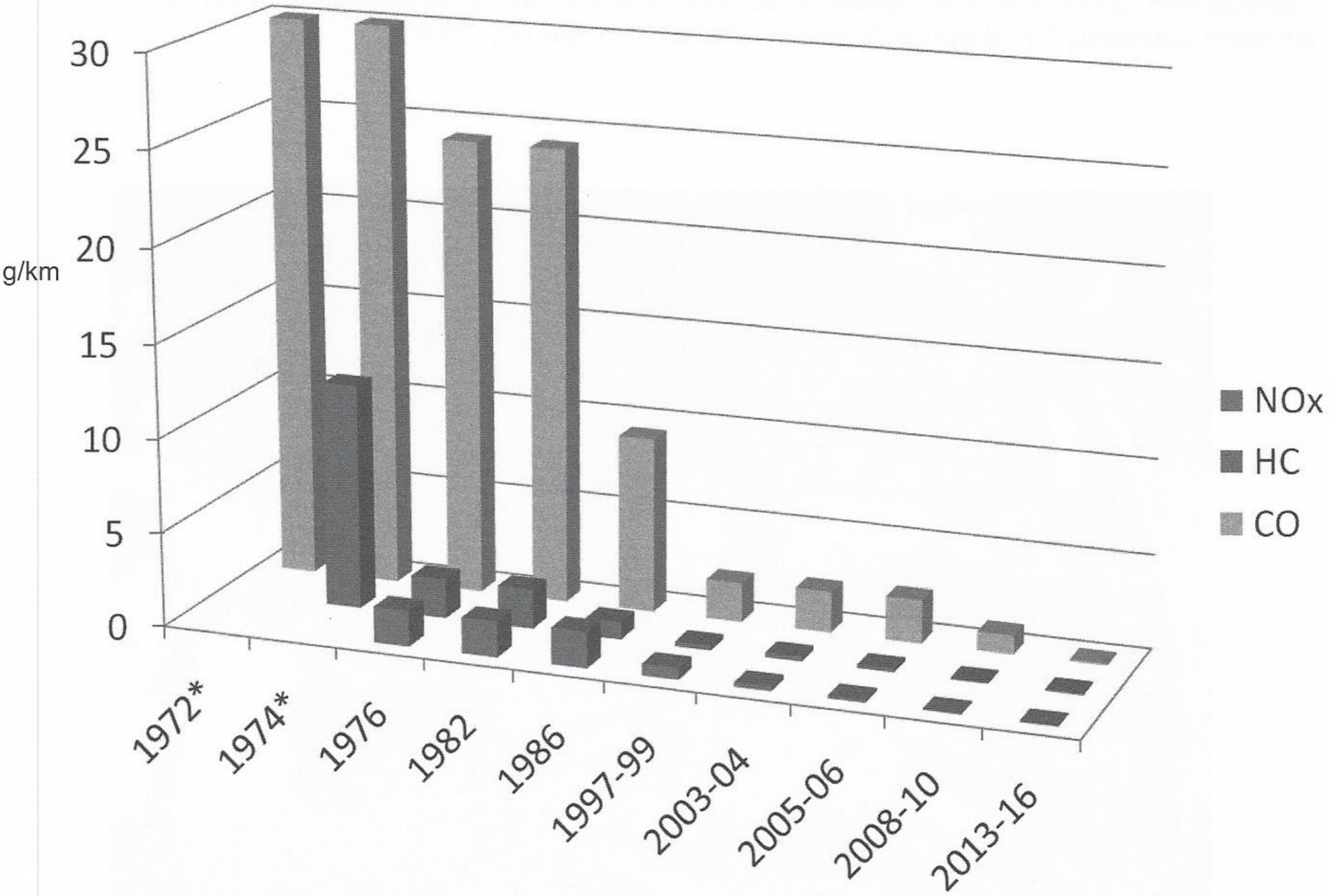
These older engines were idling faster with leaner mixtures, that many technicians felt justified in tampering with. Naturally, once tampered with, these vehicles no longer met the emission requirements that they were required to. And then fuel injection followed, leading to the engine management systems we have today. Australia has implemented the European Union's Euro IV emission standards for all light duty petrol vehicles from January 2006.



Emission level reductions

Over this time, there have been significant reductions in the level of vehicle emissions, both exhaust and evaporative emissions. Much of the more recent changes are generally invisible to us Technicians, software, a few extra sensors and a Fault Lamp taking care of it. But the wheel will turn again and as manufacturers grapple with tighter restrictions; particularly with Diesel engines, we will probably begin to see external changes as we did way back in the "seventies".

This chart indicates the diminishing level of allowable exhaust emissions for light duty petrol vehicles in Australia:



Worldwide Testing Standards and Procedures

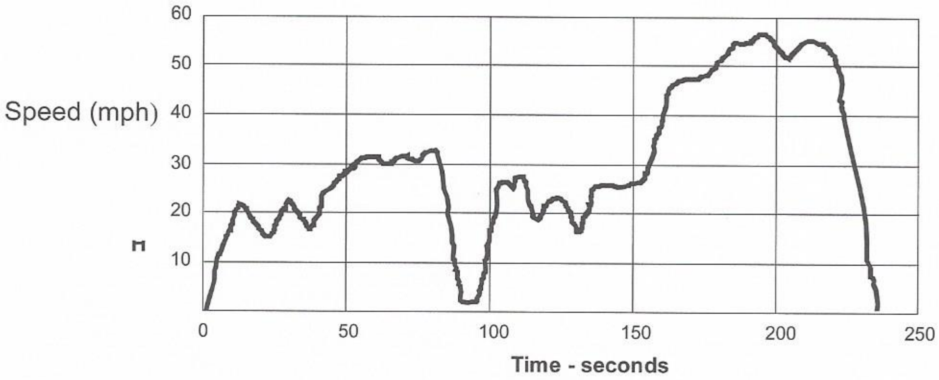
There have been a number of different testing and emission level standards implemented around the world. The big hitter has long been the California Air Resources Board (CARB). In the mid 1960's CARB were the first to implement strict emission reductions and these have since spread to other states of the US. Japan and Europe were also grappling with their own versions of testing and emission limits. Australia had implemented versions of the US regulations and has more recently aligned itself with the European Union's Euro IV standard. More strict Euro V regulations will be introduced from November 1st, 2013.

All of the differing standards involve the vehicle driven on a dynamometer in a particular drive cycle over varying distances and time. Drive cycles vary with each standard as authorities try to determine a drive cycle that best matches their everyday driving environment. The Euro drive cycle takes over 25 minutes and involves varied speed, acceleration and idle periods. Euro III standards must be met for 80,000 kilometres or up to 5 years from new. Euro IV standards (implemented in Europe in 2005, and Australia 2006) require standards be met for up to 100,000 kilometres or 5 years. Future Euro VI standards (to be introduced in 2013) raise the bar again by requiring the emission standards to be within specifications for 160,000km or 5 years!

Evaporative emissions are tested in a Sealed House for Evaporative Determination (SHED). Here the vehicle is placed in a sealed room and evaporative emissions seeping from the vehicle are measured over a period of time.

In-Service Emission Testing

The CARB also wanted to make sure that once in service, vehicles still complied with emission requirements. The Inspection and Maintenance (I/M240) test was developed to glean the critical elements of the original drive cycles into a much shorter cycle that was easier to implement in the after market. The I/M240 did not roll out universally across the US but it is required in some states before annual registration is renewed. Other individual states will develop and implement their own procedures for in-service testing.



Inspection & Maintenance (I/M) 240 Trace

When presented for the test at a certified "Smog Station", a scan tool is attached and confirms that all OBDII Monitor Tests have been completed (this is referred to as "System Readiness" for the I/M240 test). The test procedure involves the use of a special inertia dynamometer to simulate vehicle loads at various speeds during a 240 second drive cycle that includes acceleration, deceleration and cruise modes over approximately two kilometres. A "Smog" technician drives the vehicle following a test cycle displayed on a computer screen.

This drive cycle is similar (but much shorter) to how manufacturers test for emissions and ensures tested vehicles meet the OBDII regulations.

Some states of the US are content with a System Readiness status as a requirement for re-registration, whilst other states require the full I/M240 drive cycle. Some states are considering a much simpler Acceleration Simulation Mode (ASM) test run at 40 km/h on a dynamometer to replace the drive cycle. There is still a lot of contention as to what is a valid drive cycle to measure in-service emissions.

Australian National In-Service Study

In 1996 and again in 2005 studies were commissioned in Australia to determine an appropriate drive cycle for in-service testing. The National In-Service (NIS) study aims to develop an Australian Composite Urban Emissions Drive Cycle (CUEDC) for light duty petrol engines. This is an attempt to develop a short drive cycle that matches driving in our cities and provides a realistic measurement of vehicle emissions which corresponds to the requirements for new vehicles.

Powertrain Management System

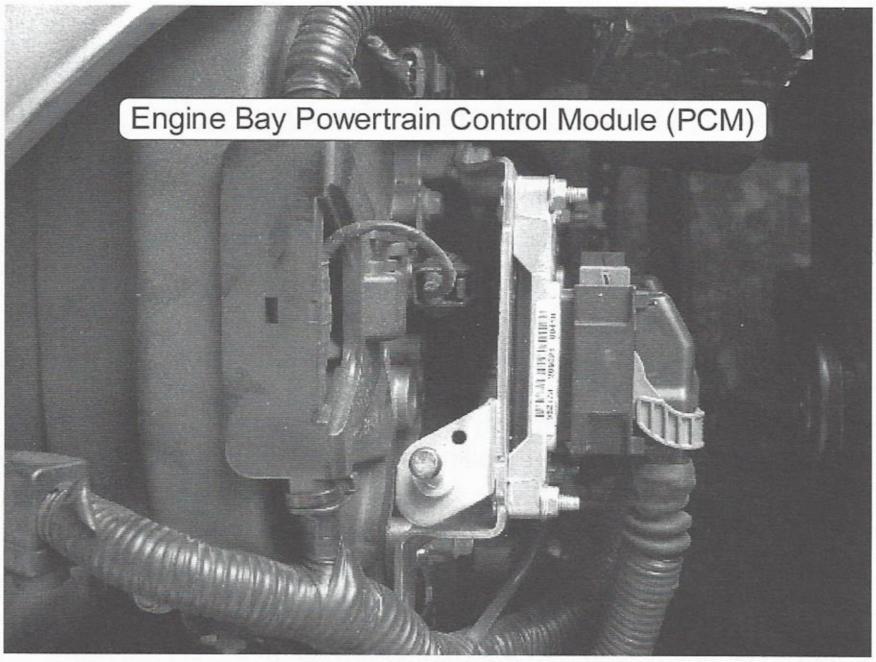
The modern Powertrain Management System is at the centre of On Board Diagnostics. It has two major components, called hardware and software.

Hardware

- Input sensors and switches, and feedback sensors
- The Powertrain Control Module (PCM)
- Output actuators and solenoids, as well as interconnecting wiring (some critical terminals are even gold plated).

Note!

Gold plated terminals may be used on low current devices, connectors and mating harnesses to improve electrical stability and to enhance corrosion resistance.
Gold plated terminals that are damaged should be replaced with gold plated terminals.
Modern hardware including the PCM is usually very durable and should not be the first component to be replaced.



Software

Software is a very long and complicated set of instructions and values stored in the PCM. It follows these instructions every time it is powered up by the ignition switch. Software is comprised of two parts:

1. Program

The Program is the list of instructions and the order that they must be carried out in. This is the "What to do and When to do it" requirements. The program may be very similar for a variety of engines of the same make and type.

2. Calibration

The Calibration information are tables of values for all of the output functions that the PCM controls. This is the "How much and for How long" requirements.

The calibration is usually unique for the:

- Body type
- Engine type and size
- Transmission type
- Other systems fitted (including ABS, Traction Control, Stability Control etc.)

The software enables the PCM to make the engine start and run. It also provides the strategy to control and minimise emissions, optimise fuel economy and provide good driveability. Within this software, the OBD strategy is monitoring the emission systems as designed by the manufacturers and required by law.

Note!

It has become common for manufacturers to update the software a number of times during the life of a vehicle to overcome problems and driveability concerns that emerge.

Powertrain Control Module (PCM)"Reflash"

Most powertrain control modules have the ability to be reprogrammed or "reflashed" via the OBD diagnostic connector. Usually this can only be done using the manufacturer's scan tool. Access to these software updates is usually only available to factory dealers.

Note!

The independent technician needs to employ strategies that will keep them up to date with the availability of these updates for different vehicles.

PCM Replacement

Some vehicles require that a replacement PCM is configured with the Program and Calibration values that were stored in the original PCM. This requires configuration data to be downloaded from the original PCM using the factory scan tool. This configuration data is then up loaded into the new PCM. This process minimises the number of PCM's that the manufacturer has to handle as the same PCM will work in a whole range of vehicles; once it is loaded with the correct Software. If the original PCM has "fried", the factory dealer uses a longer process to load "As Built Data" using the factory scan tool.

Note!

Many vehicles have security devices limiting access to; or removal of the PCM. Shear bolts that secure the PCM and hold shield plates in place, limit easy access and removal for increased vehicle security. They also control bolt torque, minimising distortion of the PCM housing.

Open Loop Fuel Control

When richer (and some cases leaner) air fuel ratios are required (starting, cold running, acceleration, power, some cases at idle), the PCM shifts the fuel control into Open Loop. In Open Loop the oxygen Sensor signal is not used and fuel injected will be a % rich or lean of the base engine calibrations. Some vehicles use a Lean Cruise Mode to reduce fuel consumption whilst cruising.

Closed Loop Fuel Control

Closed loop fuel control is initiated when the engine is required to run at the stoichiometric air-fuel ratio of 14.7:1. This is for most periods of engine operation. Switching of the Oxygen Sensor is used by the PCM to maintain this air fuel ratio. The fuel control system is said to be in Closed Loop because it monitors the effects of its' fuel injection (feedback) and then corrects it accordingly.

Fuel Trim

The PCM for a particular engine and vehicle combination is programmed with the same base fuel injection Calibrations. However, the actual fuel requirements for every engine in that engine-vehicle combination is slightly different. Fuel Trim refers to compensation that the PCM must make for variations in these fuel injection requirements. This varies from one engine to another. A negative Trim value indicates that fuel is being reduced (from base calibrations) to compensate for a rich condition, whilst a positive Trim value indicates that fuel is being increased (from base calibrations) to compensate for a lean condition.

Note!

The Fuel Trim values displayed on the scan tool are relative to the particular load and speed condition of the engine at the time.

There are two parts to the Fuel Trim;

- Short Term Fuel Trim
- Long Term

Short Term Fuel Trim (STFT)

In Closed Loop mode, the fuel injected is constantly adjusted to get the Oxygen Sensor to switch around the stoichiometric point (air fuel ratio of 14.7:1). The amount this varies from calibrated fuel values is called the Short Term Fuel Trim. It is displayed as a % and can run up to +/- 25% from the calibrated value.
The Short Term Fuel Trim values are NOT retained after the ignition is switched OFF.

Long Term Fuel Trim (LTFT)

After a period of time running in Closed Loop, the PCM "learns" the Short Term Fuel Trim values and these are stored in the Keep Alive Memory as new Long Term Fuel Trim values. These corrections are added to the base calibration values and used as the starting point in fuel injection quantities from that point onwards. It is displayed as a % and can run up to +/- 25% from the calibrated value.

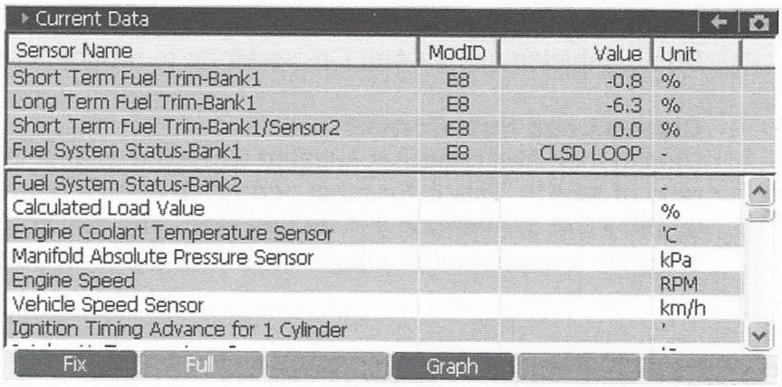
The LTFT values ARE retained in the Keep Alive Memory after the ignition is switched OFF.
In Open Loop operation, the LTFT values are used for fuel injection control, not the STFT values.

Note!

Long Term Fuel Trim values will be lost if the KAM is cleared or the battery is disconnected. On V engines, the scan tool will display STFT1 or LTFT1 and STFT2 or LTFT2.
The numbers refer to bank 1 and bank 2.

LTFT is updated from STFT information:

	LTFT	STFT
Engine starts with cleared KAM Engine runs in closed loop	0%	10%
After period of running LTFT is updated	10%	0%



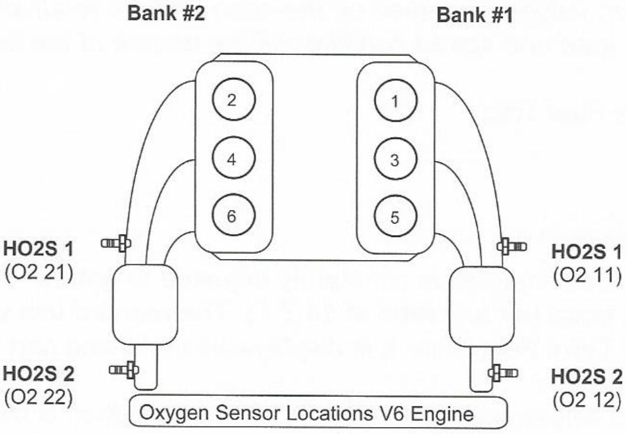
▸ Current Data

Sensor Name	ModID	Value	Unit
Short Term Fuel Trim-Bank1	E8	-0.8	%
Long Term Fuel Trim-Bank1	E8	-6.3	%
Short Term Fuel Trim-Bank1/Sensor2	E8	0.0	%
Fuel System Status-Bank1	E8	CLSD LOOP	-
Fuel System Status-Bank2			-
Calculated Load Value			%
Engine Coolant Temperature Sensor			℃
Manifold Absolute Pressure Sensor			kPa
Engine Speed			RPM
Vehicle Speed Sensor			km/h
Ignition Timing Advance for 1 Cylinder			°

Fix
Full
Graph

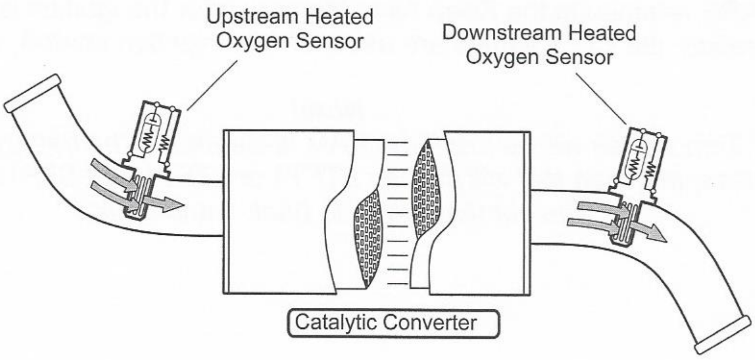
Oxygen Sensor Designations

The Oxygen Sensors are given number designations based on their placement in the exhaust system. On Inline engines, number 1 sensor will always be the one closest to the engine (upstream) and is called Bank 1 HO2S 1 (or may be O2 11). The downstream sensor is called Bank 1 HO2S 2 (or O2 12).


Bank #2
Bank #1
2
4
6
1
3
5
HO2S 1
(O2 21)
HO2S 1
(O2 11)
HO2S 2
(O2 22)
HO2S 2
(O2 12)

Oxygen Sensor Locations V6 Engine

On "V" configuration engines, the sensor on the number #1 cylinder side is identified as Bank 1 HO2S 1 (or O2 11). The other upstream sensor on the second bank is identified as Bank 2 HO2S 1 (or O2 21). Each Oxygen Sensor is given a number consecutively down the exhaust pipe, Bank 1 HO2S 2 (O2 12) and Bank 2 HO2S 2 (or O2 22).


Upstream Heated
Oxygen Sensor
Downstream Heated
Oxygen Sensor
Catalytic Converter

Before On-board Diagnostic (OBD)

The first electronic engine management systems had a fairly basic “on board” diagnostic capability. Diagnosis was often initiated by grounding pins or turning a test screw on the ECM. Voltage blips or lamp flashes provided a limited number of codes. This was enough information then, but modern OBD demands greater diagnostic capability for the technician.

How did OBD originate?

Common use of the term “On Board Diagnostics” (OBD) emerged from the state of California in the US. The California Air Resources Board (CARB) was fighting off pollution caused by motor vehicles and introduced OBD regulations for vehicles sold in the state of California for the 1988 model year.

On Board Diagnostics refers simply to the ability of an electronic engine management system to carry out self diagnosis. In its simplest form this has meant a technician hooking up a code reader or scan tool and extracting Diagnostic Trouble Codes (DTCs) logged automatically by the PCM (Continuous Test) or conducting an engine running self test (On Demand Test).

The OBD strategy is programmed to notify the driver or technician of a system failure by lighting the MIL (Malfunction Indicator Lamp) whenever there is the potential for a rise in emissions from that vehicle. This also includes potential increase in evaporative emissions.

The OBD strategy will control:

- Diagnostic self testing
- Recording the test results
- Test Fail action requests.

OBD Terminology - SAE J1930

With the introduction of OBD systems, a worldwide SAE (Society of Automotive Engineers) Standard has been implemented by vehicle manufacturers and abbreviated terms are used to describe system components. A good understanding of the J1930 will also help to understand the OBD and data scan tool lingo.

Examples are below:

DTC	Diagnostic Trouble Code
DTM	Diagnostic Test Mode
ECL	Engine Coolant Level
ECM	Engine Control Module
ECT	Engine Coolant Temperature
EEPROM	Electrically Erasable Programmable Read Only Memory
EFE	Early Fuel Evaporation
EGR	Exhaust Gas Recirculation
EI	Electronic Ignition
EM	Engine Modification
EVAP	Evaporative Emission
FC	Fan Control
FF	Flexible Fuel
FP	Fuel Pump
GEN	Generator
GND	Ground
HO2S	Heated Oxygen Sensor

OBD Diagnostic Trouble Codes (DTC's) - SAE J2012

In the past, most vehicle manufacturers simply have listed DTC's as a two or three digit code: eg. code 17 or code 117. OBDII requires that the industry include more information in the codes. The OBD II code structure contains a letter and a four digit number, for example:

- P0117, ECT Circuit Low Input
- P1348, Gas (LPG) Tank Sensor Low Input.

Note!

The last two digits of the OBDII codes may not refer to the same meaning as the older two digit style codes.

DTC Structure

The Letter:

Identifies the functional area reporting the fault:
B = Body
C = Chassis
P = Powertrain
U = Network Communications.

First Digit:

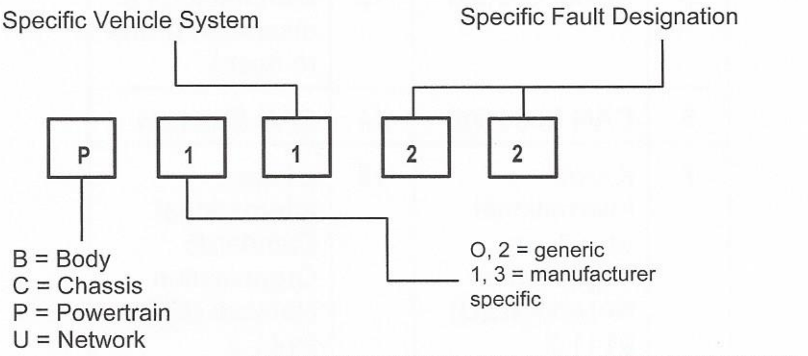
Indicates if the code is generic (0 or 2 = generic) or manufacture specific (1or 3 = specific).

Second Digit:

Indicates the vehicle system:
1 = Fuel and Air Metering
2 = Fuel and Air Metering (injector circuit malfunctions only)
3 = Ignition System or Misfire
4 = Auxiliary Emissions Control equipment
5 = Vehicle Speed Control and Idle Control System
6 = Trip Computer Output Circuit and other related outputs
7 = Transmission
8 = Transmission.

Last Two Digits:

Indicates the component or section of the system with the fault.



Nissan X Trail P1122 Throttle Position Motor or Circuit Fault

OBD Diagnostic Connector - SAE J1962

A standard 16 pin Diagnostic Connector is used on all OBDII systems (SAE standard J1962) and its location in every vehicle is stipulated under this OBDII standard.

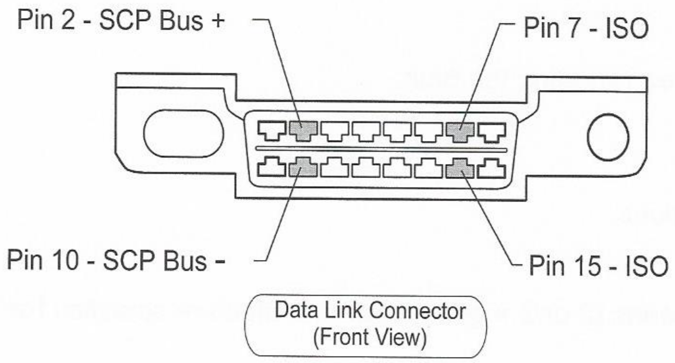
Note!

Some manufacturers may vary the pins within the connector for their own communication.

Note!

The Diagnostic Connector may have a different name dependant on the manufacturer:

- *Diagnostic Data Link*
- *Data Link Connector*
- *Assembly Line Diagnostic Link*
- *Assembly Line Communication Link*
- *Test Connector*



Diagnostic Connector Pin Allocations:

Pin #	Assignments	Pin #	Assignments
1	Manufacturer's discretion	9	Manufacturer's discretion
2	Bus+ Line - SAE J1850	10	Bus - Line - SAE J1850
3	Manufacturer's discretion	11	Manufacturer's discretion
4	Chassis Ground	12	Manufacturer's discretion
5	Signal Ground	13	Manufacturer's discretion (Ford-re flash)
6	CAN Bus High	14	CAN Bus Low
7	K Line - International Standards Organisation Network (ISO) 9141-2	15	L Line - International Standards Organisation Network (ISO) 9141-2
8	Manufacturer's discretion	16	Vehicle Battery Positive

Pin #6 of the Connector is used for CAN High,
Pin # 14 for CAN Low.
Pin #2 is used for SCP Bus+,
Pin #10 is used for SCP Bus- (manufacturer's communication - Ford).
Pin #7 (and sometimes #15) are used for ISO 9141 communication.
Pin # 16 is used for battery power.
The other pins are used by the manufacturer's at their own discretion. An example of this is in the Commodore, using pin #9 for ABS communication.

Note!
Although many manufacturers have used this style of connector, this does not mean that the engine management system is running full OBDII strategy.

On Board Diagnostics I (OBDI)

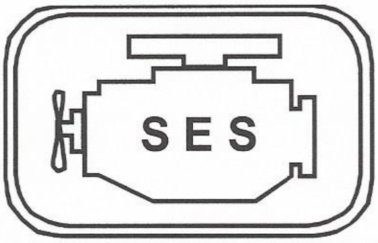
The first stage of US OBD requirements from 1988 were relatively simple compared to those required today.
They consisted of monitoring sensor and actuator failure and included the:

- Exhaust Gas Recirculation (EGR) system
- Fuel Delivery system
- Oxygen Sensor
- Powertrain Control Module.

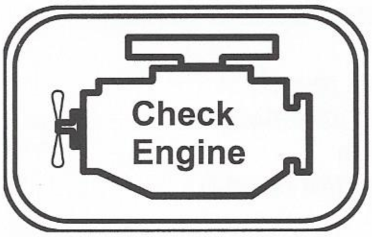
A warning lamp was required to illuminate when emission related faults were detected alerting the driver of an emission system failure. A Diagnostic Trouble Code (DTC) would be logged in the PCM and the vehicle would operate in either a sensor default strategy or Limp Home Mode. If these situations occurred, exhaust emissions would be excessive.

The lamp is called a Malfunction Indicator Lamp (MIL). The MIL may also be known as:

- Check Engine Lamp
- Service Engine Soon (SES) Lamp.



Service Engine Soon



This system became known as OBDI.

Note!

Not all vehicles of this era had a MIL Lamp. Many Australian built vehicles (whilst not OBDI) did not have a MIL Lamp either eg: AU Falcon.

On Board Diagnostics II (OBDII)

For the 1996 model year, the California Air Resources Board (CARB) introduced new stricter regulations that were called OBDII. These were to improve air quality by identifying vehicles exceeding emission standards. These stringent requirements were added to the US Federal Clean Air Act.

OBDII requires the monitoring of the performance of emission systems components as well as their obvious failures (which is all OBDI did).

The OBDII system monitors virtually all emission control systems and components that can affect exhaust or evaporative emissions. In most cases, malfunctions must be detected before emissions exceed 1.5 times the applicable standards.

System monitoring includes:

- Comprehensive Component Monitor
- Fuel System Monitor
- Misfire Detection Monitor
- Evaporative Emission Leak Check Monitor
- EGR System Monitor
- Oxygen Sensor Monitor
- Catalyst Efficiency Monitor
- Secondary Air Injection System Monitor

The OBDII strategy will report:

- Fault Code (DTC) information
- Freeze Frame data
- Readiness status (I/M Ready)

The key to these OBDII Monitor tests is that the PCM will monitor various aspects of each of these systems during normal vehicle operation (Continuous Monitors), and by creating an excursion from normal operation (Non-Continuous Monitoring). For example, fuel injection will be increased to see how quickly the Oxygen Sensor responds.

Types of Monitor Tests

There are two types of Monitors:

- Continuous
- Non-Continuous

Continuous:
These monitors run whenever the ignition is switched ON and the engine is running: Comprehensive Component Monitor, Fuel System Monitor and Misfire Detection Monitor.

Non-Continuous:
The remaining monitors require certain conditions such as speed, acceleration, deceleration, fuel level, ambient and other conditions to be met to run. If the specific conditions are not met then the Monitor cannot report if there are any faults with that system. Most cases of normal driving will allow the Monitor Tests to run.

OBDII regulations have become increasingly tighter with regular updates since their introduction in the USA in 1996.

Note!

OBD system stores information to determine which Non-Continuous vehicle Monitors have completed testing.

If a Monitor Test has run, the system status test will indicate DONE (all tests are completed) or PENDING (test not completed) will be set.

Drive Cycles and Trips

There are various trips and drive cycles that need to be understood by the technician, as well as some of the different terms for these that are used by some manufacturers.

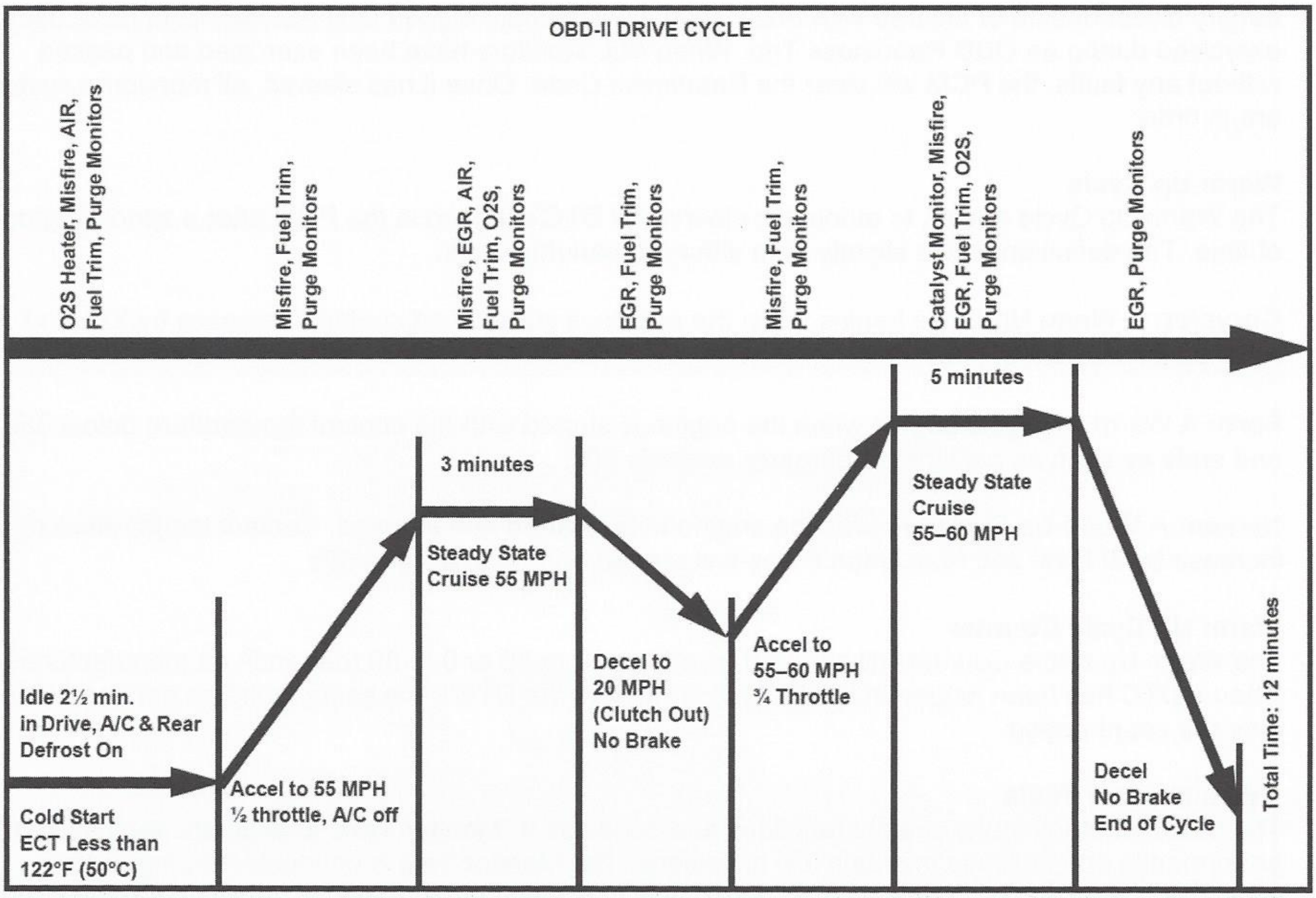
Drive Cycle

A Drive Cycle begins when the engine is started (engine cold or hot) and ends when the engine is stopped. It can be a driving or static running test on a vehicle in the workshop to verify a driveability symptom or it's repair.

A Drive Cycle may require specific drive methods, such as a number of idle periods, engine to reach operating temperature, steady vehicle speed per time and acceleration at certain throttle positions.

A Drive Cycle can be a general or specific cycle of driving events. Everyday driving by the owner or a road test by a technician is also a Drive Cycle.

Example of an OBD II Drive cycle


OBD-II DRIVE CYCLE
O2S Heater, Misfire, AIR, Fuel Trim, Purge Monitors
Misfire, Fuel Trim, Purge Monitors
Misfire, EGR, AIR, Fuel Trim, O2S, Purge Monitors
EGR, Fuel Trim, Purge Monitors
Misfire, Fuel Trim, Purge Monitors
Catalyst Monitor, Misfire, EGR, Fuel Trim, O2S, Purge Monitors
EGR, Purge Monitors
Idle 2½ min. in Drive, A/C & Rear Defrost On
Cold Start ECT Less than 122°F (50°C)
Accel to 55 MPH ½ throttle, A/C off
3 minutes
Steady State Cruise 55 MPH
Decel to 20 MPH (Clutch Out) No Brake
Accel to 55–60 MPH ¾ Throttle
5 minutes
Steady State Cruise 55–60 MPH
Decel No Brake End of Cycle
Total Time: 12 minutes

OBD Readiness Trip

An OBD Readiness Trip is a specific method of driving a vehicle and is used to perform all Monitor Tests. Readiness Trip begins when the engine is started and is completed when all monitored system tests have been completed. This can take place over one or more Drive Cycles. The System Readiness status will be confirmed as complete at the end of this Trip if all Monitor Tests pass. On Ford vehicles, the Readiness Code (P1000) will be cleared.

Monitor Trip

A Monitor Trip is a specific method of driving a vehicle that will initiate and complete a SINGLE Monitor Test. A Monitor Trip begins when the engine is started (engine cold or hot) and ends when the engine is stopped. During the trip the Monitoring system can detect a fault. This trip may relate to a single monitored system. A technician that has repaired a specific emission fault and wants to ensure the DTC won't return, may run the Monitor Trip relating to that system.

System Readiness

An OBDII scan tool will display the On Board System Readiness status. The scan tool will display the supported monitors on the vehicle and the status of all these monitors (Complete or Incomplete) at that time. The reason for this status is that when a US vehicle is presented for it's annual emission test (a re-registration requirement in some states), the "Smog Testing" facility will ensure that all Monitors have been completed before the vehicle will be admitted to the IM/240 Test (Inspection and Maintenance).

Readiness Code P1000 (Ford)

The Readiness Code P1000 will be logged whenever the PCM Keep Alive Memory is cleared (either battery disconnected or cleared with Scan Tool). It will remain logged until ALL Monitors have been exercised during an OBD Readiness Trip. When ALL Monitors have been exercised and passed without any faults, the PCM will clear the Readiness Code. Once it has cleared, all monitored systems are in order.

Warm Up Cycle

The Warm Up Cycle relates to automatic clearing of DTC's logged in the PCM after a specified period of time. The definition varies slightly from different manufacturers.

Chrysler: A Warm Up Cycle begins when the engine is started and coolant increases by 22°c and reaches a minimum of 71°c.

Ford: A Warm Up Cycle begins when the engine is started with the coolant temperature below 35°c and ends as soon as coolant temperature exceeds 70°c.

Nissan: A Warm Up Cycle requires the engine to be started and stopped. Coolant temperature must increase by at least 20°c from when it was last started and must exceed 60°c.

Warm Up Cycle Counter

The Warm Up Cycle Counter will start the count from 0 to 40 or 0 to 80 (depends on manufacturer) when a DTC has been logged in the PCM. It will delete the DTC if the same fault has not been logged over the count period.

OBDII Monitor Tests

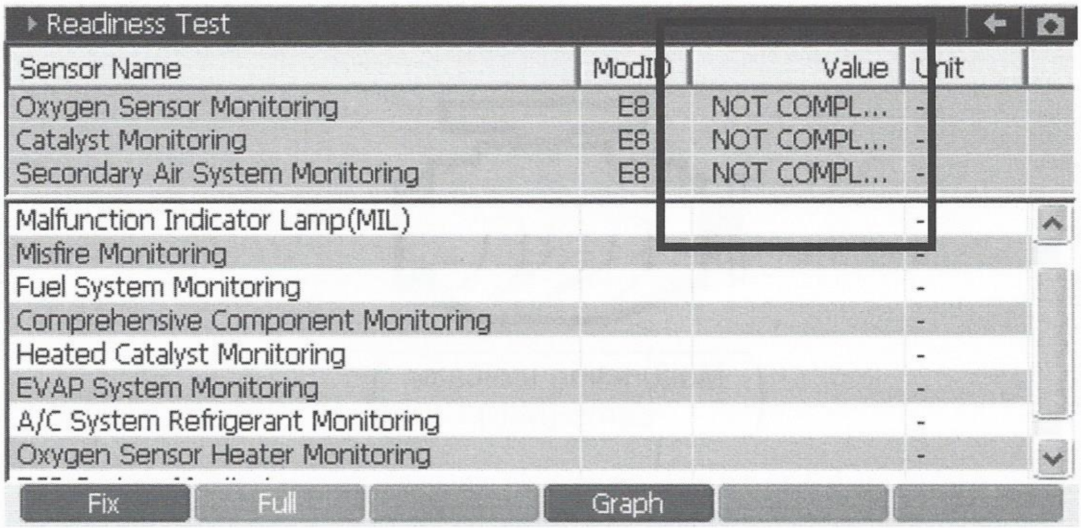
The OBDII strategy looks at eight functions and conducts a "Monitor Test" to evaluate each system's performance and ability to maintain low emissions. The Monitor Test is conducted during normal everyday driving, which is termed a Drive Cycle. It may also be conducted by a technician following a specific set of driving procedures (either a Readiness Trip or an individual Monitor Trip).

The Monitor Tests are:

- Comprehensive Component Monitor *
- Fuel System Monitor *
- Misfire Detection Monitor *
- Evaporative Emission Leak Check Monitor
- EGR System Monitor
- Oxygen Sensor Monitor
- Catalyst Efficiency Monitor
- Secondary Air Injection System Monitor

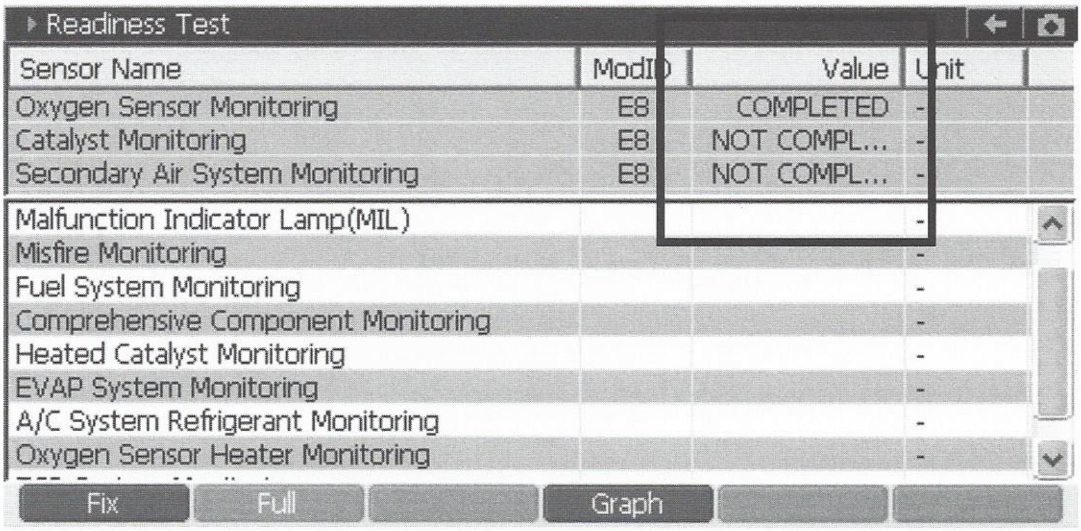
Note!
*Continuous Monitors are indicated with *.*

Note!
If there is a fault with a sensor or actuator, then related Monitor Tests will not be run and DTC's will be logged.



Sensor Name	ModID	Value	Unit
Oxygen Sensor Monitoring	E8	NOT COMPL...	-
Catalyst Monitoring	E8	NOT COMPL...	-
Secondary Air System Monitoring	E8	NOT COMPL...	-
Malfunction Indicator Lamp(MIL)			-
Misfire Monitoring			-
Fuel System Monitoring			-
Comprehensive Component Monitoring			-
Heated Catalyst Monitoring			-
EVAP System Monitoring			-
A/C System Refrigerant Monitoring			-
Oxygen Sensor Heater Monitoring			-

Examples of a generic scan tool
showing progressive completion of
various monitors

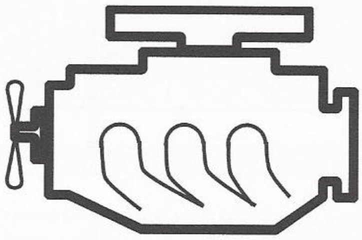


Sensor Name	ModID	Value	Unit
Oxygen Sensor Monitoring	E8	COMPLETED	-
Catalyst Monitoring	E8	NOT COMPL...	-
Secondary Air System Monitoring	E8	NOT COMPL...	-
Malfunction Indicator Lamp(MIL)			-
Misfire Monitoring			-
Fuel System Monitoring			-
Comprehensive Component Monitoring			-
Heated Catalyst Monitoring			-
EVAP System Monitoring			-
A/C System Refrigerant Monitoring			-
Oxygen Sensor Heater Monitoring			-

Comprehensive Component Monitor (CCM)
This is a Continuous Monitor. The Comprehensive Component Monitor (CCM) monitors for faults in any powertrain electronic component or circuit that provides input to or output from the PCM that can affect emissions, but is not monitored by any other monitor. This checking refers to detecting an input fault when the signal from a sensor does not match the values expected by the PCM. Outputs are monitored for proper response to PCM commands. Components for which functional monitoring is not feasible will be monitored for circuit continuity and out of range values if applicable. The CCM begins whenever the engine is started. Many of the same CCM tests are conducted during on demand self test.

Inputs monitored during the CCM include:
MAF, IAT, ECT, TPS, CMP, A/C Pressure and Fuel Tank Pressure (FTP).

Output functions monitored include:
Fuel Pump and injectors, A/C Cut Out Relay, IAC, Trans Shift Solenoids, Torque Converter Clutch, Intake Manifold Runner, Canister Purge and Canister Vent Solenoids.



Malfunction Indicator Lamp (MIL)

Fuel System Monitor

This is a Continuous Monitor. The Fuel System Monitor is a self test strategy within the PCM that monitors the adaptive fuel table. The PCM uses the adaptive fuel table to compensate for normal variability of the engine and fuel system components caused by wear or aging.

During normal vehicle operation, if the fuel system appears biased lean or rich, the adaptive fuel table will shift the fuel delivery calculations to remove the bias. The adaptive fuel strategy learns these corrections while in closed loop. These corrections are stored in the Long Term Fuel Trim table.

The table resides in the Keep Alive Memory and is used to correct fuel delivery while in Open or Closed Loop. As the components continue to change and the table learns the corrections, some values in the table may reach the calibrated limit. This means that the adaptive fuel table can no longer compensate for additional changes in the fuel system and a DTC is logged indicating that the emission levels have probably exceeded OBDII regulations.

The Fuel System Monitor will also conduct a test to determine if a rich condition is being caused by excessive vapour from the Evaporative Emission System.

Note!

Idle and deceleration conditions are excluded from Fuel System Monitor testing.

Misfire Detection Monitor

This is a Continuous Monitor. Misfire is defined as the lack of combustion in the cylinder due to the absence of spark, fuel or compression. Any combustion that does not occur within the cylinder/s at the proper time is also a misfire.

The Misfire Detection Monitor detects fuel, ignition or mechanically induced misfires. The intent is to:

1. Protect the catalyst from permanent damage
2. Alert the driver of an emission system fault by illuminating the MIL Lamp.

Note!

When the engine misfire is sufficient to damage the catalyst,
the Malfunction Indicator Lamp (MIL) will flash at a rate of one flash per second.

The misfire strategy could also be affected by the Fuel Delivery System, Comprehensive Components, Vacuum System, Evaporative Purge System and mechanical failures.

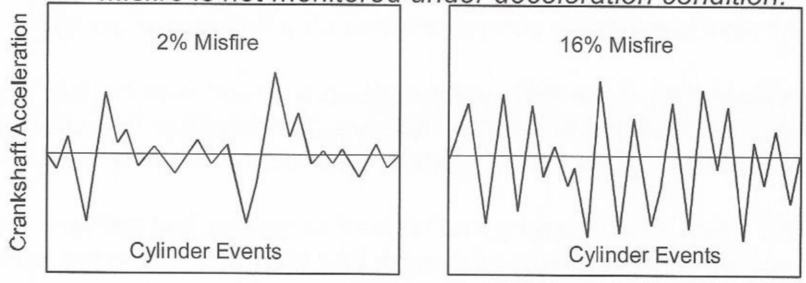
The Misfire Detection Monitor is not a system of components but rather a strategy programmed in the PCM that utilises the Crankshaft Position Sensor signal to provide information relating to the exact speed of the engine at any moment in time.

Acceleration of the crankshaft due to each cylinder firing is determined from crankshaft rotational velocity by the Crankshaft Position Sensor. The PCM time stamps each signal and calculates the time between their edges. When a misfire occurs the cylinder that has not fired, (piston will travel slower) will slow the rotation of the crankshaft. The acceleration values are compared and processed within the PCM. A power loss greater than a given threshold is labelled a misfire. A DTC will be logged.

The misfire will be either a random or a regular misfire. The PCM will specify which cylinder/s has misfired by the DTC logged (eg. P0301 - number one cylinder has misfired). If the misfire is regular, the injector/s to the misfiring cylinder/s will be cut. The PCM will look at the Camshaft Position Sensor to determine which injector/s need to be disabled.

Note!

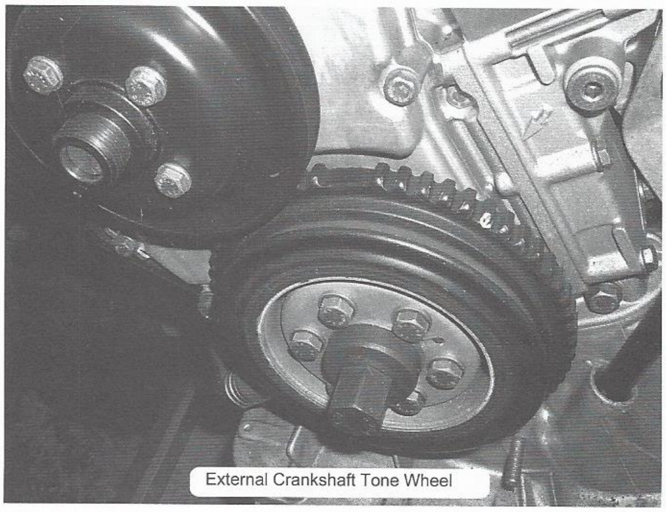
Misfire is not monitored under deceleration condition.



Misfire Monitoring

Note!

External Crankshaft Tone Wheels can also be found on the flywheel at the rear of the engine.



Misfire Categories

OBDII lists two categories of misfire depending on how regularly they occur; Type A and Type B.

Type A Misfire

If a certain number of misfires are detected within a 200 revolution period, these are identified as "Type A" misfires. They can cause damage to the catalytic converter due to high temperatures. A Type A misfire will cause the MIL Lamp to flash at a rate of once per second whilst the misfire continues. If the fuel injector is disabled to the misfiring cylinder/s, then the MIL Lamp will stay ON continuously.

Type B Misfire

If a certain number of misfires are detected within a 1,000 revolution period, these are identified as "Type B" misfires. These can lead to increased exhaust emissions. The MIL Lamp will only illuminate if this re-occurs during a second successive Drive Cycle.

Profile Correction

Profile Correction is a means to apply correction factors to the Crankshaft Position Sensor signals to compensate for noise such as trigger wheel irregularities and other engine variations. Profile correction is learned during closed throttle decelerations from 100 to 60 kph (in fuel cut-off mode), without pressing the brake. This is learned once or twice after the Keep Alive Memory has been cleared.

Rough Road Correction

During periods of high torsional "noise" through the driveline (due to driving over very rough roads) the Misfire Detection Monitor is disabled. The ABS wheel speed sensors may be used for rough road detection. When the ABS ECM determines a rough road condition, it communicates this to the PCM which disables the Misfire Detection Monitor if it (the PCM) determines the signal is affected by noise and is not a true misfire event.

Newer methods used for misfire control involves software changes. The complex Monitor software program can detect most; but not all rough roads. The software diagnostics will have the characteristics of a rough road programmed in. These characteristics will be used to check against the Crankshaft Position Sensor signal. If the diagnostic detects rough road, the Misfire Detection Monitor will be disabled.

Vehicles with auto trans may have additional software functions for the Torque Converter Clutch (TCC) lock-up strategy. The TCC will be disengaged when a misfire is suspected, this isolates the engine form the rest of the driveline to minimise any effect from the drive wheels on the crankshaft rotation.

Note!

Misfire control may be disabled if the fuel tank level is below 15%.

Before the misfire monitor can become operational on an FG Falcon, a PCM misfire learning mode must be conducted. This is usually carried out at the dealership at pre-delivery.

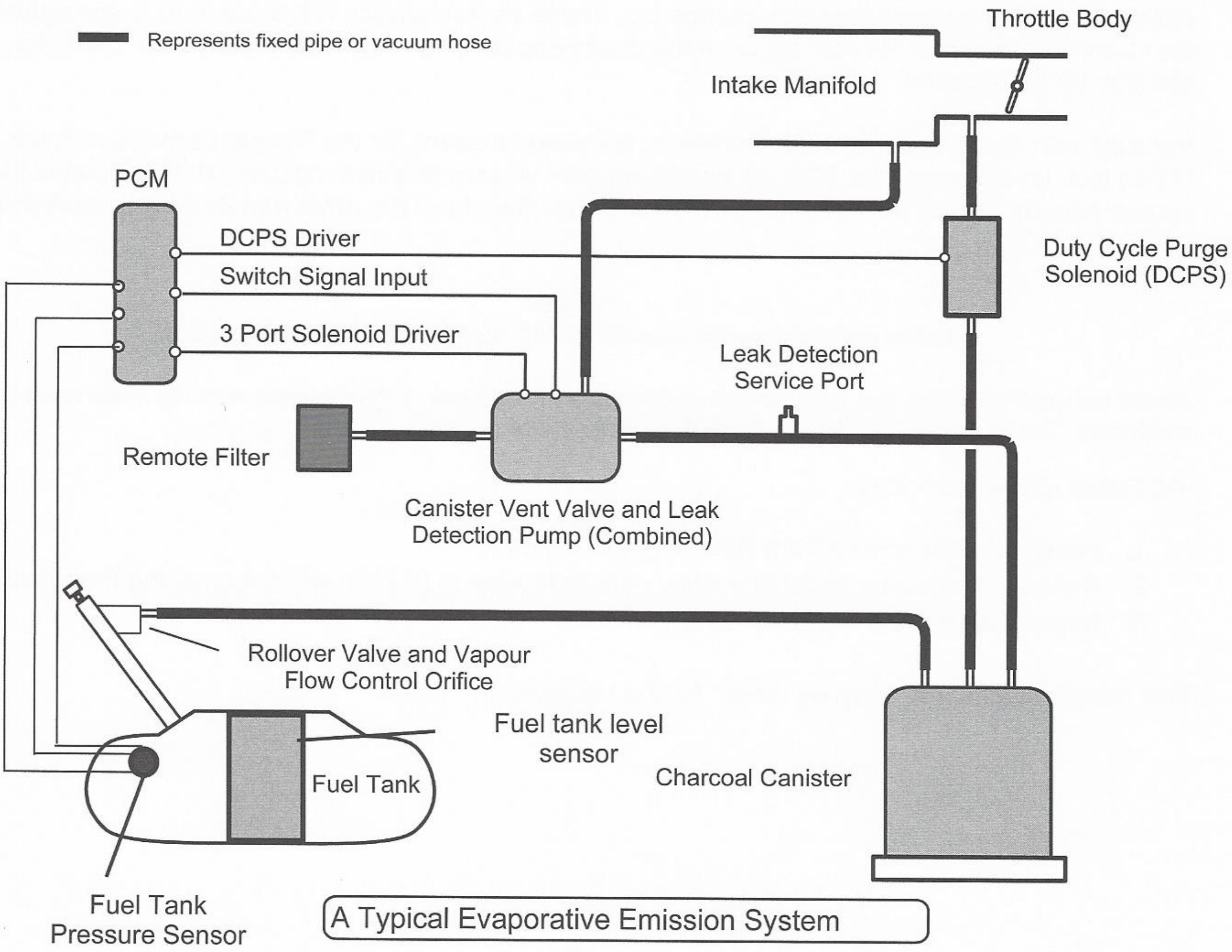
FG Falcon Misfire Learn Cycle,

1. Accelerate the vehicle from stationary to 105km/h.
2. Release the throttle pedal and allow vehicle to slow to 65km/h without touching the brakes.
3. Repeat steps 1-2 a further three (3) times.

This then activates the "learning mode" for the combustion misfire

Evaporative (Evap) Emission Leak Check Monitor

This is a Non-Continuous Monitor. The Evaporative (EVAP) Emission Leak Check Monitor is a strategy designed to detect a leak from a hole equal to or greater than 0.5 mm anywhere in the evaporative system. It first tests for a 1.0 mm leak (the earlier OBDII standard) and if this passes, it then tests further for the 0.5 mm leak threshold. This Monitor looks at the ability of the EVAP system to both maintain a vacuum and hold a slight pressure to confirm a leak exists. A failed test would indicate that the EVAP system is allowing fuel vapours to escape into the atmosphere.


Represents fixed pipe or vacuum hose
Throttle Body
Intake Manifold
PCM
DCPS Driver
Switch Signal Input
3 Port Solenoid Driver
Duty Cycle Purge Solenoid (DCPS)
Leak Detection Service Port
Remote Filter
Canister Vent Valve and Leak Detection Pump (Combined)
Rollover Valve and Vapour Flow Control Orifice
Fuel tank level sensor
Fuel Tank
Charcoal Canister
Fuel Tank Pressure Sensor

A Typical Evaporative Emission System

EVAP System Components

A "conventional" Canister Purge system has some additional control and sensing components added:

- Fuel Tank Pressure Sensor
- Canister Vent Valve

Fuel Tank Pressure Sensor

The Fuel Tank Pressure Sensor transducer is usually located at the fuel tank, but may be at the canister or some other remote location in the EVAP system. It measures the absolute pressure of the EVAP system. Pressure or vacuum readings are sent to the PCM for the Monitor Tests.

Canister Vent Valve

The Canister Vent Valve solenoid is located at the Canister. When opened, it allows atmospheric air to displace vapours from the canister that have been drawn into the intake manifold during canister purging. When closed by the PCM, it seals the EVAP system for the Monitor Tests.

Canister Purge Valve

The Canister Purge Valve solenoid is usually located close to the engine compartment. It meters fuel vapour into the intake manifold as directed by the PCM during normal vehicle operation. It is also used to create the Target Vacuum during the Monitor Test.

EVAP Monitor Test

This test applies vacuum to the EVAP system and monitors the decay of that vacuum. It may include a Vapour Generation Test if the 1.0 mm Leak Vacuum Test fails.

Note!

Fuel level is an important input to the PCM. This determines how much fuel is in the tank. The amount of fuel in the tank will affect the rate of change in vapour pressure.
For this Monitor Test to run, the fuel level must be between 15% and 85%.

Vacuum Test - 1.0 mm Leak

- Canister Vent Valve solenoid is closed by the PCM, sealing the EVAP system from the atmosphere.
- Canister Purge Valve is opened momentarily to apply a Target Vacuum to the fuel tank and EVAP system. Target vacuum is measured by the Fuel Tank Pressure Sensor. The Canister Purge Valve remains closed during the rest of the test.
- PCM then monitors the decay in target vacuum over a pre-set period of time.
- If the decay is too fast, the PCM determines there is a leak greater than 1.0 mm and logs a DTC.

Note!

For some vehicles, if the target vacuum cannot be reached after refuelling (recent change in fuel tank levels) and purge vapour is excessive (Canister Purge Valve is held open very long but still can't reach target vacuum), then the PCM will log a "Fuel Cap Off" DTC.

Note!

If the initial target vacuum is exceeded, it indicates a fault with the Canister Purge Valve. The Monitor test will be aborted with a failure DTC. The Valve may not be sealing correctly. This will continually bleed extra fuel (vapour) into the intake system and may provide engine running rich DTC's.

Vapour Generation Test

If the 1.0 mm vacuum decay threshold continues to be exceeded after three tests, a Vapour Generation Test will be conducted:

- Canister Purge Valve is closed
- Canister Vent Valve is opened, tank returns to atmospheric pressure as determined by the Fuel Tank Pressure Sensor.
- Canister Vent Valve is now closed and the fuel tank and EVAP system is sealed from the atmosphere.
- Fuel Tank Pressure Sensor monitors pressure build up due to vapour generation caused by normal vehicle movement on the road.
- If the vapour pressure build up does not meet certain thresholds, a major leak is confirmed and a DTC will be logged.

Vacuum Test - 0.5 mm Leak

If the 1.0 mm test passes, the PCM will conduct the 0.5 mm test.
Again, vacuum decay is monitored but this time at idle. If vacuum decay exceeds a threshold, a DTC will log. Otherwise, the Monitor Test is given a pass.

Note!

Some vehicles used an electric pumping system to pressurise the system to test for leaks.

Exhaust Gas Recirculation (EGR) System Monitor

This is a Non-Continuous Monitor. The EGR system helps control Oxides of Nitrogen (NOx). When opened, the EGR will allow small amounts of exhaust gas to enter the inlet manifold and into the combustion chamber to reduce peak combustion chamber temperatures and reduce NOx.

EGR Systems

Two common systems are the:

- Differential Pressure Feedback EGR (DPFE) System (Ford)
- Electric Stepper Motor EGR System.

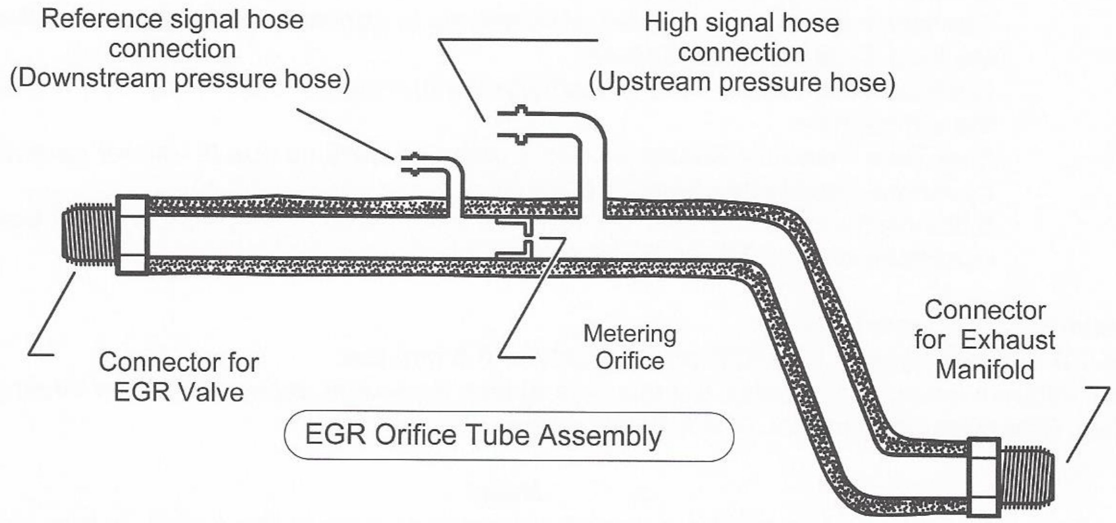
Differential Pressure Feedback EGR (DPFE) System

The DPFE sensor is a ceramic capacitance type pressure transducer. The sensor has two vacuum hoses from the EGR pipe to the sensor. One is a large hose called upstream (High signal) and the other is a smaller hose called downstream (Reference signal). The sensor is powered by a 5 volt supply from the PCM.

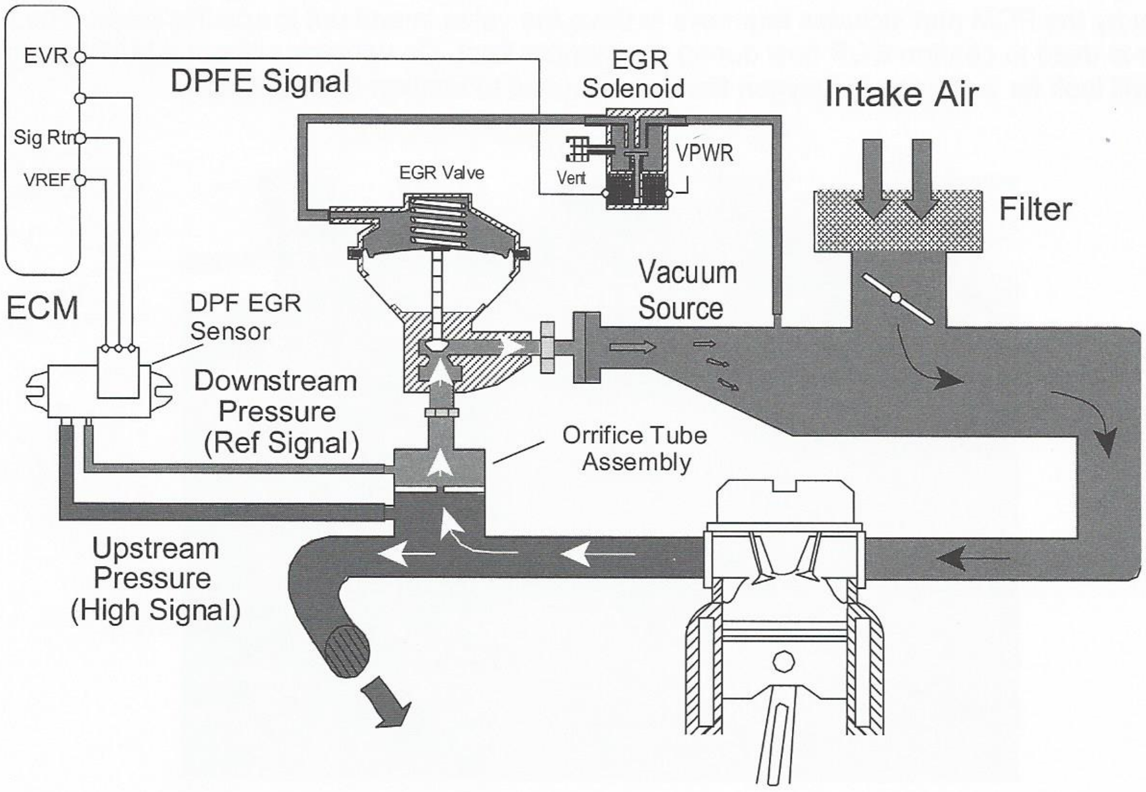
The exhaust system pressure (at upstream hose) and the drop in pressure across the metering orifice (at downstream hose) is used by the PCM to calculate the flow rate of exhaust gas. The DPFE sensor outputs a voltage proportional to the pressure drop across the orifice.
When the pressure is Low (7.5 kPa) the voltage will be Low (1.5 volts). As the pressure (and EGR flow) increases the sensor output voltage will also increase.

Typical DPFE Sensor Data

Differential Pressure		Voltage
PSI	kPa	
0	0	0.45
1.08	7.46	1.48
2.17	14.9	2.51
3.25	22.36	3.54
4.34	29.81	4.56


Reference signal hose connection (Downstream pressure hose)
High signal hose connection (Upstream pressure hose)
Connector for EGR Valve
Metering Orifice
Connector for Exhaust Manifold

EGR Orifice Tube Assembly


EVR
DPFE Signal
EGR Solenoid
Intake Air
Sig Rtn
VREF
VPWR
Vent
EGR Valve
Filter
ECM
DPF EGR Sensor
Vacuum Source
Downstream Pressure (Ref Signal)
Orrifice Tube Assembly
Upstream Pressure (High Signal)

Differential Pressure Feedback EGR Operating Principle

DPFE Monitor Test

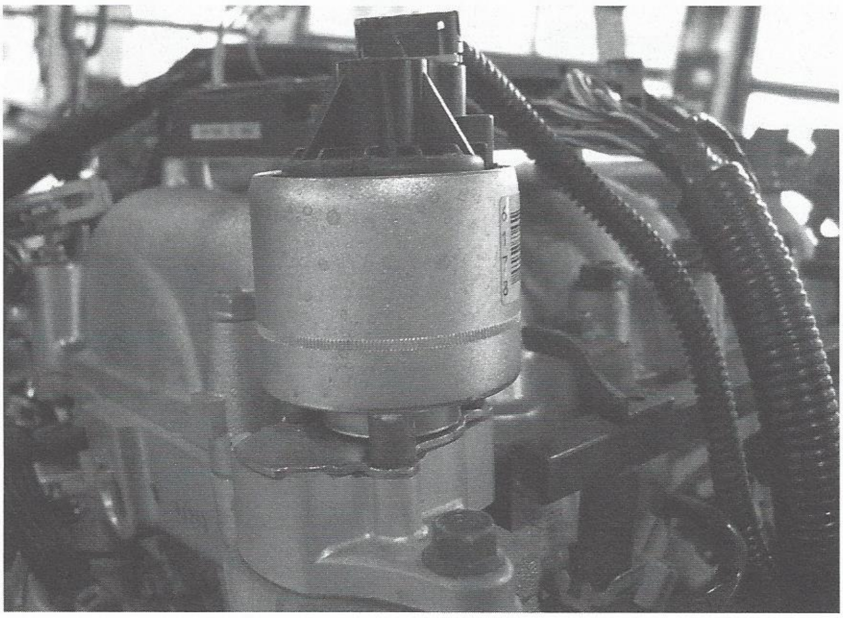
The PCM is continually looking at the integrity of the sensor and actuator circuits. If a fault occurs with any of these, a DTC will be logged. Whenever the TPS indicates idle, the PCM will look to ensure the DPFE Sensor voltage indicates no flow (This part is Continuous).

The sensor hoses are tested once per drive cycle for blockage or disconnection. The test is conducted with the EGR closed during acceleration. A voltage increase or decrease during acceleration while the EGR valve is closed may indicate a fault with a signal hose during this test.

The EGR flow rate test is performed during a steady-state (cruise) when engine speed and load are moderate and EGR Vacuum Solenoid duty cycle is high. The Monitor compares the actual DPFE circuit voltage to a desired EGR flow voltage for that state to determine if EGR flow rate is acceptable or insufficient. If there are any faults, the Monitor will log a DTC.

Electric Stepper Motor EGR System

In this system, the EGR valve is incorporated with a Stepper Motor. The stepper motor is driven directly by the PCM and includes four coils to drive the valve in and out in specific steps. The MAP sensor is used to confirm EGR flow during the Monitor Test. On vehicles without a MAP sensor the PCM will look for a change in Oxygen Sensor response to confirm EGR gas flow.

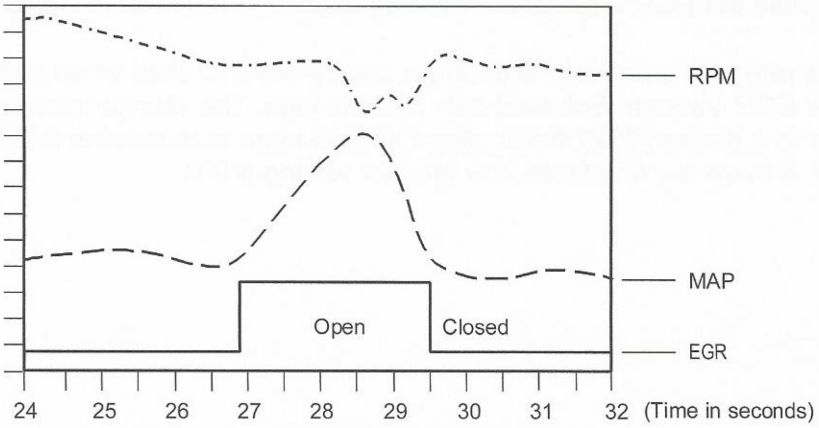


Electric Stepper Motor EGR Monitor Test

The Monitor continually checks the Stepper motor circuits for continuity and short circuits. The EGR Flow test is done by observing the effect of EGR flow on the MAP sensor signals (slight increase in manifold pressure caused by the exhaust gasses).

The EGR Monitor test is run during steady-state engine operation:

- The PCM momentarily commands the EGR ON (about 10%) while monitoring the MAP sensor. The MAP value is recorded.
- The EGR is commanded OFF and the MAP value recorded again.
- A number of these samples will be taken and the average used to determine if there are any faults with the EGR flow.
- If the expected MAP increase is not seen under certain operating conditions a DTC will be logged.



MAP change in comparison to EGR operation

Oxygen Sensor Monitor

This is a Non-Continuous Monitor. The Oxygen Sensor Monitor is a strategy designed to monitor the Oxygen Sensors for a malfunction or deterioration which can affect emissions. The Fuel System Monitor and the Misfire Monitor are completed before the Oxygen Sensor Monitor can run.

This Monitor Test is in two parts:

- The Upstream Oxygen Sensor/s (fuel control) is checked for proper output voltage and response rate (the time it takes to switch from lean to rich or rich to lean).
- The Downstream Oxygen Sensor/s (catalyst efficiency) is also monitored for proper output voltage.

Upstream Oxygen Sensor Test

The Monitor Test for the upstream Oxygen Sensors is enabled when the entry conditions have been met (engine hot and sensor active).

- The upstream Oxygen Sensor/s signal voltage amplitude and response frequency are checked. A fixed frequency fuel modulation (rich-lean-rich etc.) begins and the Sensor/s reaction to these changes is used to determine if there is a sensor fault. The PCM will look at the time between these transitions. The transition times are compared to calibrated fail parameters stored in the PCM to determine a pass or fail.

Note!

On "V" engines with an Oxygen sensor in each bank, the PCM will use an alternate phase between the banks (left lean when right rich and visa versa) to minimise torque fluctuations during this Monitor Test.

- The heater circuit is tested by the PCM switching the heater ON and OFF and measuring the current flowing through the heater circuit.

Note!

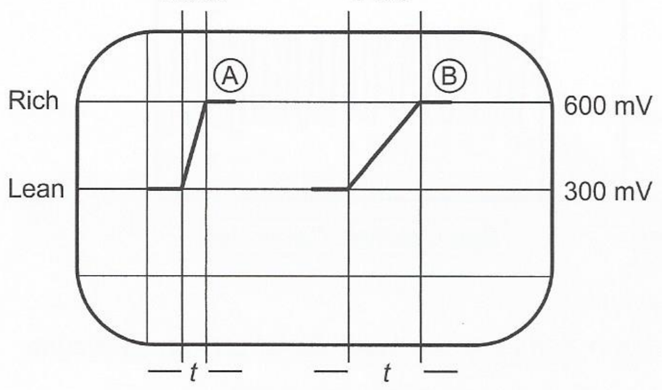
The heater will not switch ON until a predetermined period after a cold start to clear any moisture in the system and avoid thermal shock damage to the sensor if water hits it.

Downstream Oxygen Sensor Test

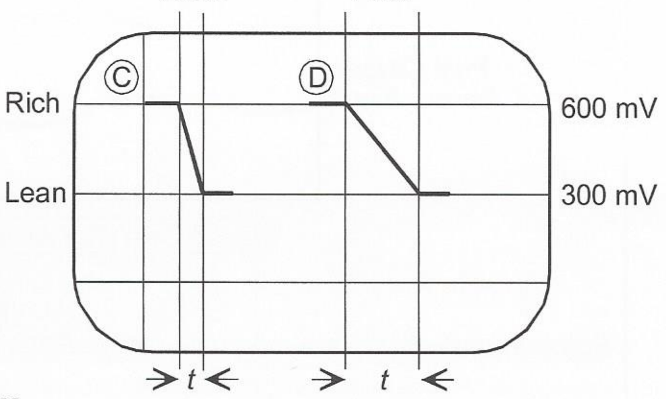
The Downstream Oxygen Sensor Test is essentially the same as the Upstream Sensors. The exception is that the PCM will not initiate fuel modulation unless the sensor has not been switching for a pre-set period of time.

Note!

On some vehicles, the Oxygen Sensor connectors may be inadvertently swapped from one bank to the other causing driveability and emission problems. Some vehicles may log a DTC for this, some may not.



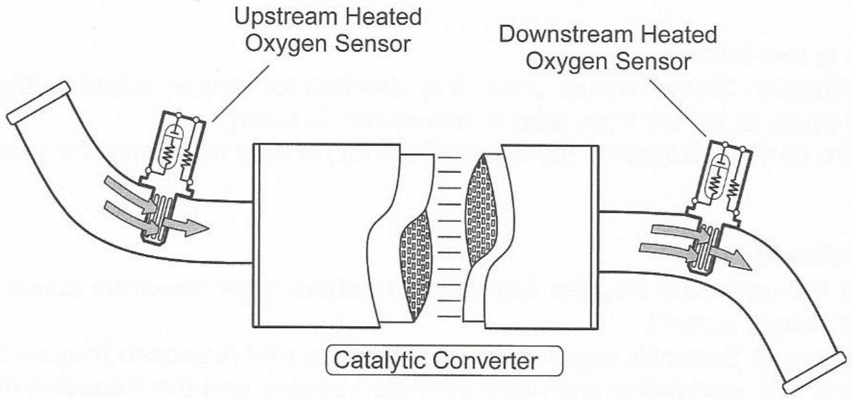
Lean to Rich



Rich to Lean

Catalyst Efficiency Monitor

This is a Non-Continuous Monitor. The Catalyst Efficiency Monitor determines when a catalyst has fallen below the minimum level of effectiveness in its ability to control exhaust emissions.


Upstream Heated Oxygen Sensor
Downstream Heated Oxygen Sensor
Catalytic Converter

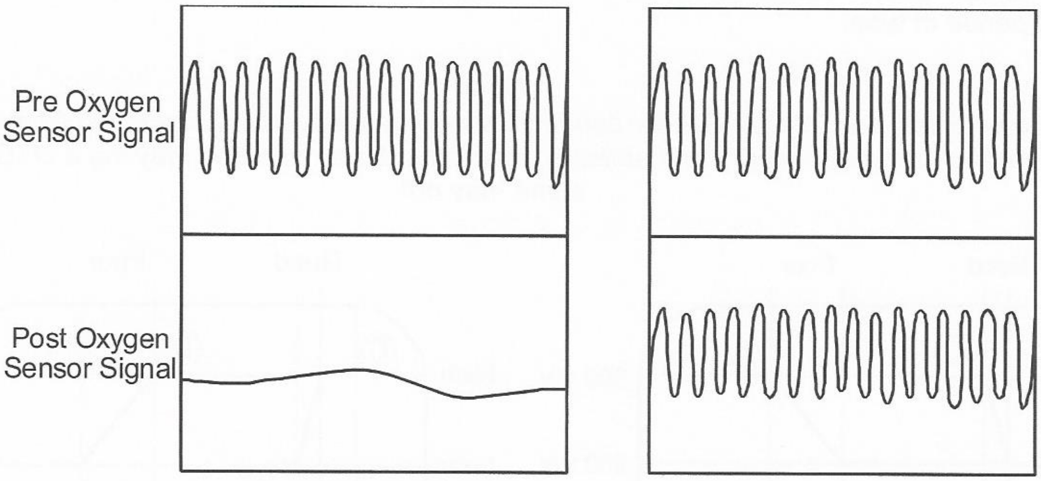
The components which make up the Catalyst Efficiency Monitor are the Upstream Oxygen Sensor/s, Downstream Oxygen Sensor/s and the Catalyst/s.

The Catalyst Efficiency Monitor uses an Oxygen Sensor before and after the Catalyst to determine the oxygen storage capacity of the Catalyst. Under normal closed loop fuel conditions, a good catalyst will have a large oxygen storage capability. This means switching of the Downstream Oxygen Sensor/s will be very slow with reduced amplitude compared to the Upstream Oxygen Sensor/s.

As the Catalyst efficiency deteriorates over time, its ability to convert and store oxygen decreases. Which means the Catalyst is no longer doing anything to the exhaust gases and so the Downstream Oxygen Sensor/s will begin to switch at a similar rate and amplitude as the Upstream Oxygen Sensor/s. If this occurs, a DTC will log and the Monitor Test fails.

Note!

Contamination of the Catalyst be phosphorus, lead, silica, sulphur, engine oils or engine coolant will prevent the converter from functioning properly. All these contaminants will have an effect on the relationship of the catalyst's oxygen storage capacity and emission performance.



Good Catalytic Converter

Bad Catalytic Converter

Note!

Some manufactures are now using Wide Band Oxygen Sensors, see Wide Band Oxygen Sensors.

Secondary Air Injection (Air) Monitor

This is a Non-Continuous Monitor. The Secondary Air Injection (AIR) system controls emissions during the first 20 to 120 seconds of engine operation by forcing air downstream into the exhaust manifolds to oxidise the hydrocarbons and carbon monoxide created by running rich at start up (assisting fast catalyst "light-up").

AIR System Components

The AIR System consists of an Electric Air Pump that provides air to the exhaust manifold and a combined Check Valve/s and Air Control Valve that allow air to pass from the Electronic Air Pump to the exhaust system while preventing hot exhaust gases from passing back to the Electronic Air Pump. An Air Bypass Solenoid is used to provide a vacuum control signal to the Air Control Valve.

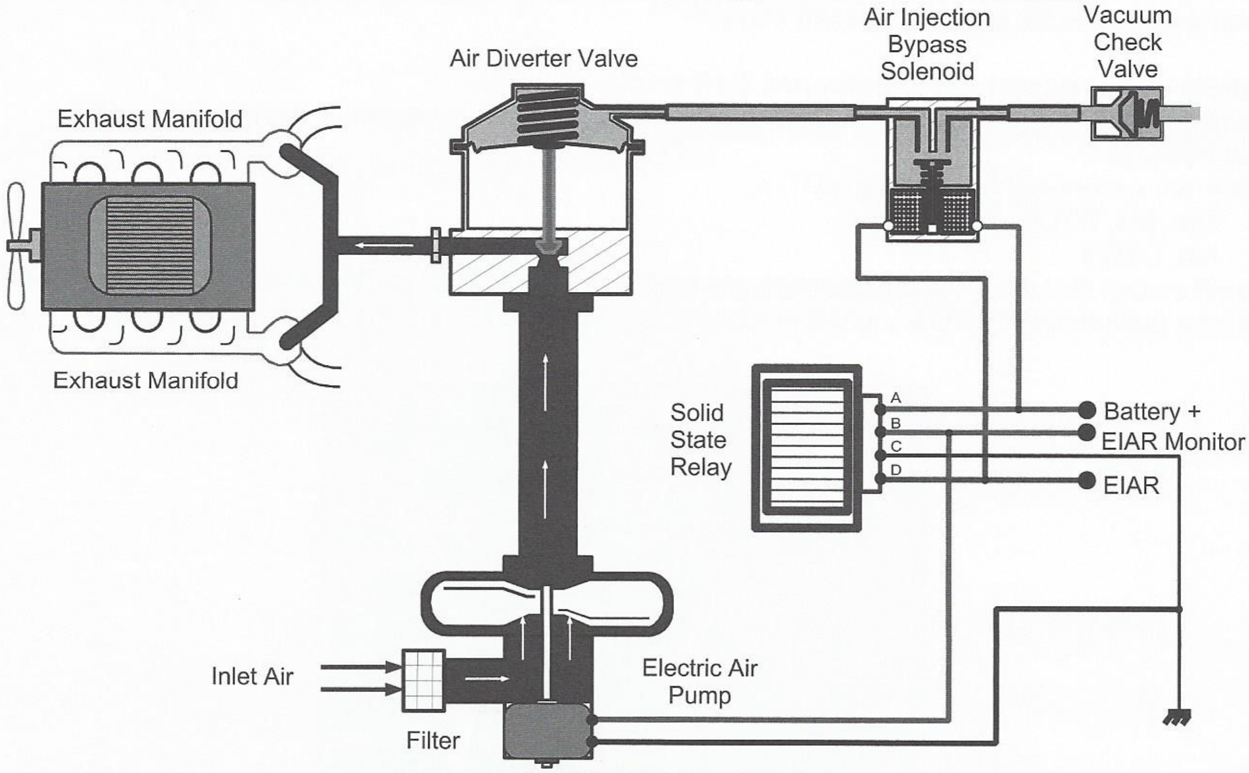
A Solid State Relay controls the Electronic Air Pump ON/OFF operation. The PCM provides a control circuit to the Solid State Relay and a circuit to monitor the Electronic Air Pump and the Solid State Relay to determine if the components are functioning properly and secondary air is present.

When the engine starts, the PCM signals the Solid State Relay and the Air By-pass Solenoid to begin system operation. The Solid State Relay provides a start up signal to the Electronic Air Pump. The Air By-pass Solenoid applies a vacuum to the Air Control Valve causing it to open allowing air to flow into the exhaust manifolds. When the catalyst is lit-up and excess air is no longer required (up to 120 seconds after starting), the PCM signals the Solid State Relay to stop pump operation and the AIR By-pass solenoid to stop vacuum supply to the Air Control Valve.

AIR Monitor Test

The Secondary Air Injection System Monitor Test determines if the AIR system is capable of pumping air into the exhaust manifold. The Monitor Test may be done in two parts. At startup when the AIR pump is normally commanded ON, or during a hot idle if the startup test was not able to be performed.

This test relies upon the Oxygen Sensor to detect the presence of additional air in the exhaust and it's leaning effect on the mixture. Monitoring of the AIR System will occur once per drive cycle and takes about 20 seconds. If AIR flow is insufficient, a DTC will log and the Monitor Test fails.



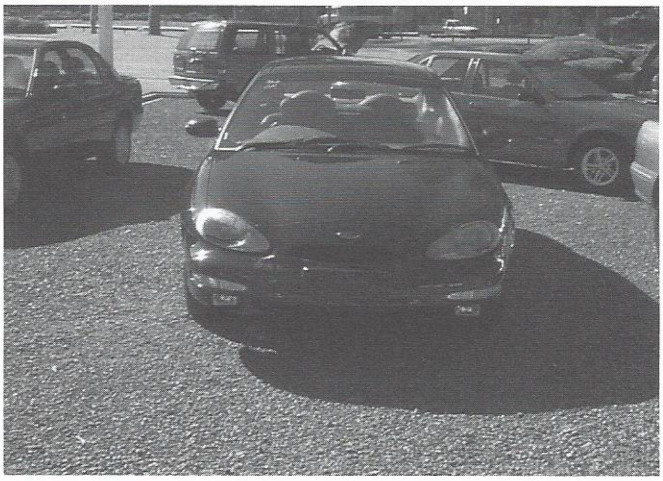
Secondary Air Injection Principle

OBDII Vehicles in Australia

True US OBDI vehicles were not seen here in any great volume (from 1988 model year to 1995 models). Up until the end of 2005 (When Australian Design Rule 79/01 or Euro III standards were introduced), greater numbers of US vehicles were built in RHD and imported into Australia but were generally downgraded to OBDI level.

This usually meant:
- Revised PCM software
- Downstream Oxygen sensors removed or non functional
- Evaporative System/Fuel Tank Pressure Sensor and Canister Vent Valve solenoid removed or non functional.

On Board Diagnostics (OBD) is a standardised approach to identifying engine management system malfunctions. However it must be remembered that the cause of most malfunctions is ultimately found with basic diagnostic techniques.



In 1996, the Ford Taurus was OBDII in the US, but the same vehicle was downgraded back to OBDI when it went on sale in the Australian Market.

Malfunction Indicator Lamp (MIL) and DTC Logic

When a malfunction is detected, a DTC may not be permanently logged or the MIL may not be switched ON.

There are essentially two kinds of DTC's:
- Non-MIL DTC's
- MIL DTC's

A malfunction that does not effect emissions logs a Non-MIL DTC, so the MIL is not switched ON. Whilst a malfunction that does affect emissions logs a MIL DTC and the MIL is switched ON.

First Drive Cycle

If the OBDII Monitor Test detects an emission malfunction during a single Drive Cycle, it will log a "Pending" DTC but NOT switch ON the MIL Lamp (the exception to this is during a Type A misfire when the MIL will flash).

Fault detected in Single Drive Cycle
If the malfunction detected in the First Drive Cycle is not detected after three consecutive Drive Cycles, the "Pending" DTC will be cleared by the PCM.

Second Successive Drive Cycle
If the OBDII Monitor Test detects the same emission malfunction during a second successive Drive Cycle, it will log a permanent DTC and switch ON the MIL Lamp.

Subsequent Drive Cycles
If the MIL is switched ON due to a malfunction in a second successive Drive Cycle, if the same malfunction is not detected again after three consecutive Drive Cycles, the MIL Lamp will be switched OFF. The DTC will remain logged for a further 40 to 80 (depending on the vehicle) Warm Up Cycles and then it will be cleared.

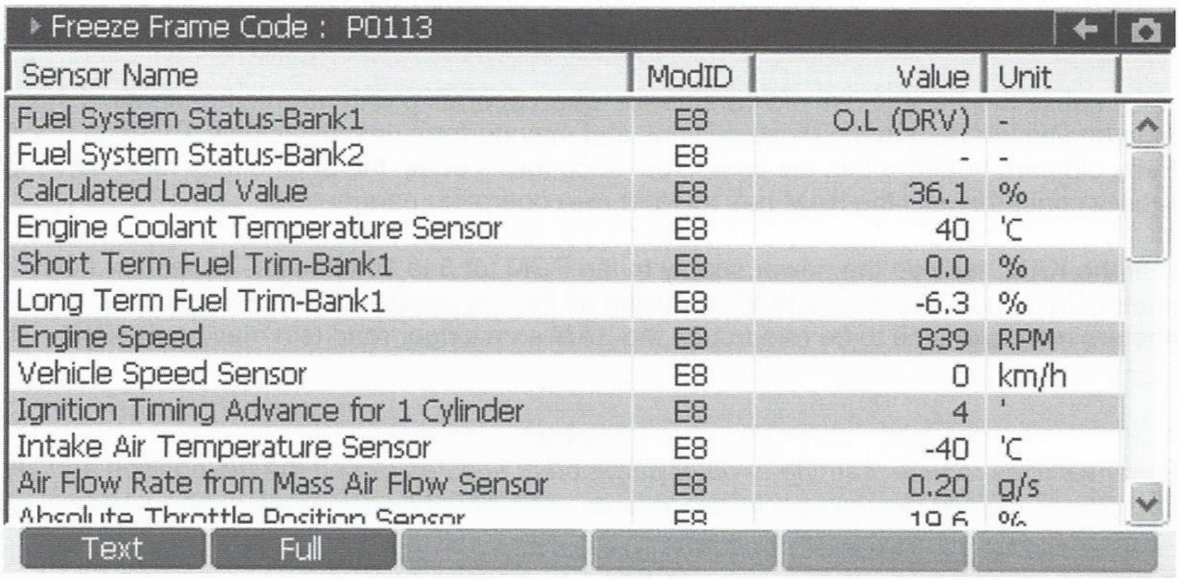
Note!
The reason for the MIL switching at the second consecutive Drive Cycle malfunction is to make sure the fault is a real fault and not just a glitch.

Note!
Non-Monitor Test DTC's can be stored in the PCM and not light the MIL, these are non emission related DTC's.

Freeze Frame Data

Freeze Frame Data provides a snapshot of conditions present and how the vehicle was driven when an emission related DTC was logged. This snapshot of data (eg. state of the engine, state of fuel control, spark, RPM, load and warm up status) "freezes" the conditions at the time of the DTC and can help in the diagnosis of the problems that caused the DTC to be logged. It can help to isolate possible areas of concern as well as rule out others.

Freeze Frame Data will not be updated if the same malfunction occurs a second time or additional DTC's are logged. If the data has reached full capacity, previously stored conditions will not be replaced unless a fuel or misfire malfunction is detected.



Freeze Frame Code : P0113

Sensor Name	ModID	Value	Unit
Fuel System Status-Bank1	E8	O.L (DRV)	-
Fuel System Status-Bank2	E8	-	-
Calculated Load Value	E8	36.1	%
Engine Coolant Temperature Sensor	E8	40	'C
Short Term Fuel Trim-Bank1	E8	0.0	%
Long Term Fuel Trim-Bank1	E8	-6.3	%
Engine Speed	E8	839	RPM
Vehicle Speed Sensor	E8	0	km/h
Ignition Timing Advance for 1 Cylinder	E8	4	'
Intake Air Temperature Sensor	E8	-40	'C
Air Flow Rate from Mass Air Flow Sensor	E8	0.20	g/s
Absolute Throttle Position Sensor	E8	19.6	%

Generic Freeze Frame Data includes:

- Vehicle speed
- ECT
- RPM
- Engine load %
- Short Term Fuel Trim
- Long Term Fuel Trim
- State of lambda control (open/closed loop)

Misfire Freeze Frame Data

To help in the diagnosis of misfire, additional Misfire Freeze Frame Data is stored when misfire is detected. Misfire Freeze Frame Data is captured at the time of the highest misfire rate (and not when the DTC is logged at the end of a 200 or 1000 revolution block like generic Freeze Frame Data).

Note!
Misfire Freeze Frame is supported on all OBDII vehicles but may not be available on all scan tools because access may vary by scan tool manufacturer.

Typical Misfire Freeze Frame Data includes:

- Vehicle speed
- RPM
- Engine load %
- Intake air temperature
- Engine-off soak time
- Engine running time
- EGR DPFE sensor
- Throttle Position
- Number of driving cycles (at least one 1,000 rev block)
- Park / Neutral Position Switch status (in Drive)
- Misfire wheel profile learned in KAM

Keep Alive Memory (KAM)

Computers are always keeping records of current running information from all input sensors as well as logged DTC's. The PCM will look back at this information before setting new parameters. After work has been carried out on the vehicle (eg. throttle body cleaning, injector service or a new sensor fitted) the PCM will still look at this old information (Long Term Fuel Trim and other learned parameters).

This may cause the PCM to use old parameters when operating with new components. If this is the case the engine will respond to those settings and may perform unsatisfactorily. Clearing the KAM will clear any old parameters within the computer. Once this is done, the engine may have some idle and driveability concerns until the KAM has relearnt new operating parameters.

To clear the KAM, remove the power supply to the PCM for 5 to 10 minutes. To relearn new parameters take the vehicle for a road test using all throttle positions and gear positions. Some new parameters may take time to be relearnt by the KAM so a longer road test may be needed.

Notes!
Some vehicles require learning of other parameters such as closed throttle position and idle air volume. These usually require special procedures and will not be relearned during a normal road test.

Some vehicles with ZF 6 speed auto transmissions require considerable driving once the KAM has been cleared.

Clearing DTCs

There are three methods for clearing DTCs from OBDII equipped vehicles:

- Clearing the DTCs with a scan tool (this method is preferred as it does not clear any other information from the vehicle, eg. security system codes and Fuel Trim values).
- Removing the power supply to the PCM (for approximately 5 to 10 minutes). This may involve a fuse or relay being disconnected.
- If the fault that caused the DTC to be logged in the memory of the PCM and the PCM has not seen the same fault in 40 to 80 (depending on the vehicle) Warm Up Cycles, the DTC will be automatically cleared from the KAM.

False DTCs

False DTCs may be logged on vehicles that do not have certain equipment levels or accessories fitted. These DTCs should be ignored. The same should apply to “ghost codes” that are logged in the PCM when connectors have been disconnected and reconnected with the ignition ON, or when service work has been carried out and the DTCs have not been cleared. These False DTCs can have you chasing problems that may not exist.

For example, during cranking with a battery that is in a low state of charge; a Ford Focus may log a P2122 DTC (Accelerator Pedal Position Sensor circuit #1, Low input). Battery voltage spikes or low battery supply to the instrument cluster may be the cause of the DTC.

If you are unsure about the DTCs that have been logged in the PCM, record, clear them and then road test the vehicle. If the DTCs do not return, you can carry on checking the real DTCs.

Some vehicles may also log a DTC if certain functions are not carried out during an Engine Running self test. This may include pressing the brake pedal, turning the steering wheel or switching the overdrive OFF button.

On Board Diagnostics III (OBDIII)

The next level of OBD is currently under discussion in California by CARB. The idea is to minimise the time between when a fault is detected and when it is repaired. The only way to do this is by using roadside readers that receive a signal from a vehicle that an emissions related DTC has been logged. The PCM also communicates the VIN number so the owner receives a letter and a time limit to have the vehicle repaired. There are a whole lot of legalities involved with this and may take a very long time to implement - if at all.

European On Board Diagnostics (EOBD)

The European version of OBDII is termed European On Board Diagnostics (EOBD). EOBD is the European Union's exhaust emissions standard. Euro IV has been adopted as Australian Design Rule (ADR) 79/02. Since mid-2008 all new model petrol fuelled light vehicles in Australia must meet these standards.

Externally, much of EOBD control hardware (sensors, PCM and actuators) are similar to those described for OBDII. The main differences between OBDII and EOBD is the way the actual drive cycles are conducted and the allowable emission levels. EOBD also includes a sub-zero temperature start-up (-7⎵C) for the Drive Cycle.

EOBD Implementation

Some existing models in the Australian market were not able to meet EOBD requirements and were dropped from the market at the end of 2005. It is also interesting to note that many vehicles that were upgraded to EOBD standard lost a little in power output in the process.

EOBD IV standards must be met for 100,000 kilometres or up to 5 years from new, with normal servicing as specified by the manufacturer.

Upgrades to EOBD

Vehicles sold in the Australian market have been upgraded to EOBD standards by implementing some or many of these improvements:

Engine Efficiency
- Powertrain software upgrades
- Compression ratio increases
- Variable camshaft timing
- Dual knock sensors - some provide individual cylinder timing control
- Faster engine warm up strategies
- Advanced EGR Systems
- Air Fuel Ratio Sensors (Wide Band Oxygen Sensor)
- Electronic Throttle Control

Parasitic Loads
- Lower viscosity oils
- Electric power steering - reduces mechanical load
- Smart charging systems - PCM controlled using less power

Catalyst Efficiency
- Catalyst upgrades
- Catalyst Monitor Sensors fitted

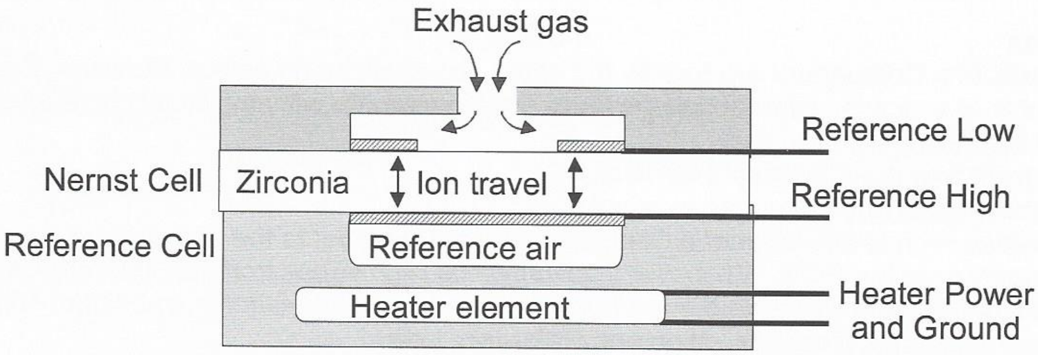
Evaporative Emissions
- Improved sealing of fuel supply systems

Driveline
- Revised shift strategies and lower torque converter lock up speed
- Revised gear ratio and number of gears transmissions.

Oxygen Sensor Types

Planar Oxygen Sensors

More manufacturers are moving away from the “thimble” type Oxygen Sensor to the Planar Type. Instead of the relatively large thimble, the planar sensor uses a flat Zirconia ceramic element around 1.5 mm thick. The electrodes, ceramic, insulation and heater are laminated together on a single strip, making it smaller, lighter, resistant to contamination and more durable.
Planar sensors reach operating temperature much quicker than thimble types and are more sensitive.
Planar operating principles are the same as a thimble type sensor.



Planar Oxygen Sensor

Wide Band Oxygen Sensors

To pass EOBD standards, some vehicles are now fitted with Wide Band Oxygen Sensors (some manufacturers refer to them as Air Fuel Ratio Sensors). Operation of the Wide Band Oxygen Sensor is different to the “switching” Zirconia Oxygen Sensor we are familiar with. The Wide Band Oxygen Sensor is able to determine exactly how rich or lean the fuel mixture is over a wide range of air/fuel ratio (unlike the switching sensor that can only detect an air-fuel ratio of 14.7:1).

> *A Narrow Band (or switching) Oxygen Sensor is only a two-state sensor. The term Nernst Cell is also used to describe the sensor’s principle named after Walter Nernst who developed the theory way back in 1899. At stoichiometric (14.7:1) air-fuel ratio it outputs a voltage of approx. 450 millivolts (0.45 Volts). Sampling approximately every 50 milliseconds, it informs the PCM that the mixture is in only one of two states; either rich or lean. The PCM then adjusts the injector duration dependant upon the signal received. This lag time between the change in states causes gaps (inaccurate readings) in corrections to the air-fuel ratio.*

The wide band sensor consists of two parts:

- A narrow band sensor (“Nernst Cell”)
- An additional Ion (or oxygen) pump section.

Wide Band Oxygen Sensor Continued

Nernst Cell

We need to look first at the “narrow band” section of this sensor. This has an atmospheric air reference chamber and an electrode (now referred to as Reference High).

This is separated from the exhaust electrode (Reference Low) by a Zirconia material. The only thing new here is that the air reference electrode is held “artificially” at a (stoichiometric) voltage level of 450 millivolts by the PCM (by one input of a comparator).

This means that as the exhaust gas oxygen content varies, differing amounts of ions will be transferred through the Zirconia material raising or lowering the voltage at the Reference High electrode. This is normal narrow band switching that we are familiar with.

Comparator

If both inputs of a Comparator are exactly the same, there will be no output. However, if one or the other input is at a slightly different voltage level, the Comparator will amplify this difference and create an output that may be

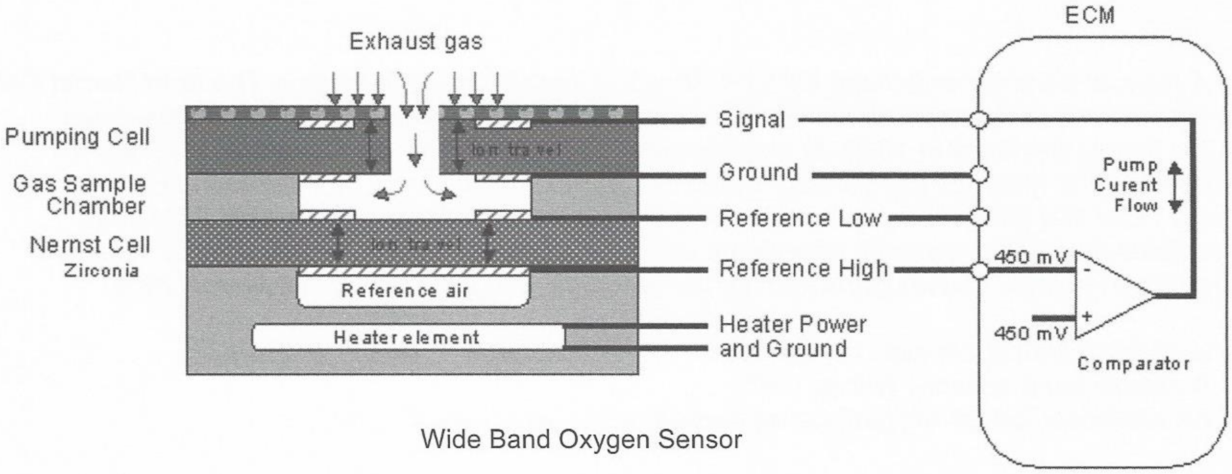
- current flow from the output terminal or
- current drain into the output terminal.

The Reference High is one input of a Comparator, the other input to the Comparator is a constant 450 millivolt supply from the PCM. Whenever the Reference High varies from the 450 millivolts it will cause the Comparator to operate the Ion Pump section to try and maintain a constant 450 millivolt difference between the Reference High and Reference Low.

Ion Pump

The Ion Pump section consists of the exhaust sample chamber, two wires and electrodes for pump current that are separated by a Zirconia material. These two terminals are the Signal High and Signal Low. A porous ion conductive material separates the exhaust gas stream and the exhaust sample chamber. When pumping current is supplied to the two pump electrodes, it will either draw additional ions from the exhaust stream into the exhaust sample chamber, or if current direction is reversed, it will push ions from the exhaust sample chamber back into the exhaust stream.

The pump is trying to balance the oxygen content of the exhaust sample chamber with that of the reference air chamber.

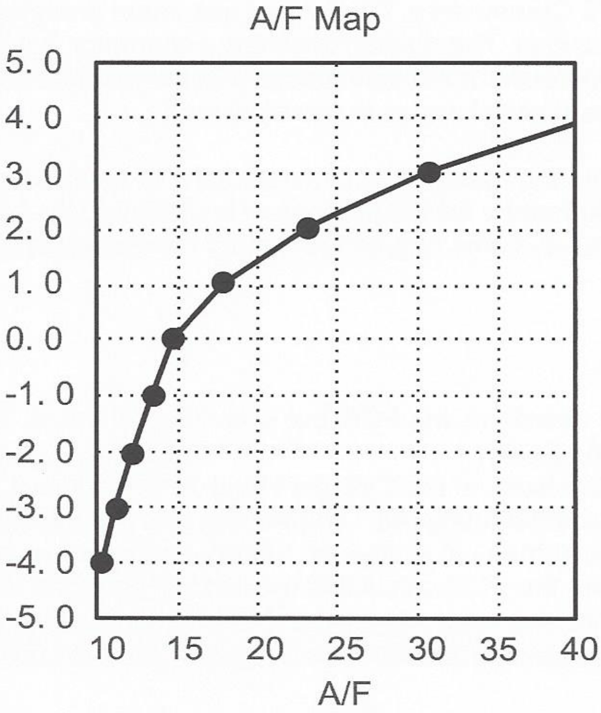


Wide Band Oxygen Sensor

In other words, oxygen is pumped away in the event of excess air in the exhaust gas (lean), and oxygen is pumped in during low residual oxygen levels (rich) by reversing the pump current. **It is the pumping current and polarity that the PCM uses to determine the actual air-fuel ratio**. This process happens extremely quickly making the Wide Band sensor more accurate.

Note!
A Scan Tool is necessary to determine the operating status of Wide Band Oxygen Sensors.

Wide Band Oxygen Sensors are usually heated and can be identified by a 6 wire connector instead of the switching sensor that has up to 4 wires.



Advanced EGR Systems

Some vehicles employ Advanced EGR Systems that are not subject to the EGR System Monitor Test, as they are controlled internally. With the implementation of independent Variable Camshaft Timing (for each camshaft), comes an additional capability to control exhaust gas recirculation internally, without the usual external EGR components. To enable internal EGR, the camshaft timing is retarded. This delays the combustion cycle and the late closing of the exhaust valve ensures some exhaust gas is drawn back into the cylinder from the exhaust manifold. The amount of camshaft retardation is varied by the PCM as required.

Smart Charging Systems

Smart Charging Systems are used to reduce load on the engine and provide better maintenance of the battery's charging requirements, improving battery life.

Most modern vehicles today (VE Commodore, FG Falcon) use smart charging to lower engine load and minimise unnecessary emissions. This system lowers the alternator Set Voltage whilst cranking and during wide open throttle operation. It will also maintain better idle stability since it can vary alternator load in response to transient changes in electrical load.

Batteries may also have a monitoring system that monitors state of health and state of charge. This enables the PCM to exercise the battery for the purpose of lengthening the battery life. If a new battery is fitted to a vehicle, some systems require the battery monitoring system to be recalibrated with a scan tool.

Battery Temperature

Battery temperature is not read directly by the PCM but is an inferred value. This function is carried out entirely by software within the PCM.

- At low vehicle speeds, the PCM looks at the Cylinder Head Temperature (CHT) sensor value
- At higher speeds, the PCM uses the Intake Air Temperature and the Vehicle Speed Sensor values to infer the ambient temperature. It then calculates the battery temperature using these values.

From these pieces of information, the PCM calculates the Set Voltage. The PCM sends a PWM signal (Command) to the alternator. The alternator will send a PWM signal (Monitor) confirmation back to the PCM (closed loop). The Set Voltage will fall within the range of 12.8 to 15.5 volts.

Note!

During an extended idle, the Set Voltage will be the lowest.

Note!

If the alternator warning lamp is ON, a PCM test will be needed to see if any faults has been logged.

Jeep Grand Cherokee Battery Temperature Sensor

The Jeep Grand Cherokee has a dedicated temperature sensor located in the centre of the battery tray to provide the PCM with actual battery case temperature.

Faster Warm up

Different manufacturers are using various strategies to speed up the engine warm up process, as this period has a major impact on emissions. Some common strategies are:

- Automatic Transmission Fluid Warmer/cooler
- Water control valve
- Electronic Throttle Control.

Auto Trans Fluid Warmer/Cooler Ford ZF Transmission

BF Falcons fitted with the 6 speed ZF auto transmission use a remote Auto Trans fluid Warmer/Cooler. When the coolant is cold, the transmission fluid heating up in the torque converter is used to add heat to the coolant in the remote Auto Trans fluid Warmer/Cooler. When both the trans fluid and coolant are hot, the Warmer/Cooler will transfer heat to the surrounding air via fins on it's body.

Water Control Valve X-Trail

The Nissan X-Trail uses a Water Control Valve to separate coolant flow from the cylinder head and the cylinder block. The Water Control Valve is located at the rear of the engine at the hot coolant outlet. The thermostat is located at the coolant inlet to the engine before the water pump.

- When coolant temperature is below 82°C, coolant flow is from the cylinder head through the Water Control Valve and back through the water pump into the cylinder head.
- When coolant temperature is between 82°C and 95°C, the thermostat is opened and coolant flow from the cylinder head travels to the radiator and back through the water pump into the cylinder head.
- When coolant temperature is greater than 95°C, the Water Control Valve now admits the flow of coolant through the cylinder block; as well as the cylinder head to travel to the radiator and back through the water pump.

Electronic Throttle Control

Many new vehicles are now fitted with an Electronic Throttle Control (ETC) system (fly-by-wire) that does not use a throttle cable. The benefits of ETC are:

- Moving parts are reduced as well as the noise transmission path of a cable
- Integration of cruise control, traction control, idle control and vehicle dynamics control
- The PCM will modify the actual throttle valve opening compared to accelerator pedal movement, based on various program strategies including the need to minimise emissions.

Note!

ETC systems have no means to alter the idle speed, it is controlled directly by the PCM. Do not attempt to alter anything on the throttle body.

ETC is a closed loop system that provides the PCM with direct feedback from the Throttle Position Sensor.

ETC System Components

The ETC system usually consists of:

- Accelerator Pedal Position Sensor
- Throttle Body with Throttle Position Motor
- Throttle Position Sensor
- PCM and associated wiring
- Throttle Fault Indicator (where fitted).

Accelerator Pedal Position Sensor

The PCM monitors the Accelerator Pedal Position Sensor to determine the driver's input. It uses this signal along with its other inputs to determine the amount of throttle opening required.

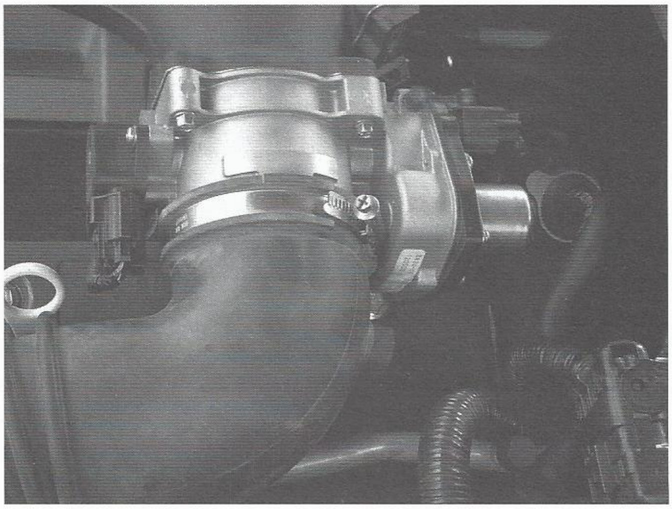
It usually contains at least two potentiometers and the combination of the two signals allows the PCM to calculate an average voltage output from the two signals. This allows the pedal position to be determined with greater accuracy if only a single potentiometer sensor was used.

Throttle Body

The Throttle body usually contains a spring mechanism that holds the throttle valve in a slightly open position (around 10% open). The Throttle Position Motor will open or close the throttle valve from this default position to provide the desired engine speed.

The Throttle Position Motor is a DC motor that drives the throttle valve through a reduction gear set. It is driven by a Pulse Width Modulation (PWM) signal, which is also called a varying duty cycle signal.

When the ignition is switched OFF, the Throttle Position Motor will remain powered for a few seconds to allow it to reposition the throttle valve to the closed position.

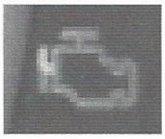


Throttle Position Sensor

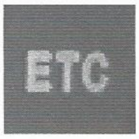
The Throttle Position Sensor contains two potentiometers and are usually of the “opposing slope” type. This means that one potentiometer signal increases in value as the throttle is opened. The other potentiometer decreases in value as the throttle is opened. This allows the throttle valve position to be determined with greater accuracy than if only a single potentiometer sensor was used.

Throttle Fault Indicator

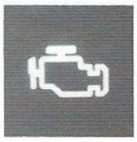
Some vehicles will also have a Throttle Fault Indicator on the instrument cluster to warn the driver if some fault is affecting engine performance.



BA Falcon



BF Falcon



FG Falcon

Throttle Position Motor

Should there be a failure of the Throttle Position Motor, the PCM will be unable to control the throttle valve. In this case, the internal spring mechanism will provide around 10% throttle opening which will allow the engine to run and be driven to a place of repair.

On some vehicles, the PCM will still have a small amount of control over engine speed. If the Accelerator Pedal Position Sensor is working normally, the PCM will vary the ignition timing to pull the engine speed lower (retarding) until the accelerator pedal is depressed and it will then advance the ignition timing to allow the full effect of the default 10% throttle position.

Accelerator Pedal Position Sensor

If the PCM cannot receive reliable information from the Accelerator Pedal Position Sensor it will disable the Throttle Position Motor so it returns to the default 10% position.

Throttle Position Sensor

If the PCM cannot receive reliable information from the Throttle Position Sensor it will disable the Throttle Position Motor so it returns to the default 10% position.

Note!

ETC systems are still affected by carbon build up at the throttle valve and bore and may require periodic cleaning to restore correct idle performance.

EOBD Monitor Tests

EOBD consists of 7 Monitor Tests:

- Comprehensive Component Monitor
- Fuel System Monitor
- Misfire Detection Monitor
- Oxygen Sensor Monitor
- Catalyst Efficiency Monitor
- EGR System Monitor (If Fitted)
- Secondary Air Injection System Monitor (If Fitted)

These functions are much as described for OBDII. The main difference is the higher rate of detection from the use of enhanced software.

EOBD MIL Lamp and DTC Logic
EOBD MIL Lamp and DTC logging logic is similar to that described for OBDII. Different manufacturers however, use slightly different terms to describe these.

Chrysler Jeep Trip Monitor
Chrysler refer to "Two Trip Faults" being required for most Monitor Tests before the MIL will illuminate.

Chrysler Jeep One Trip Faults
The Comprehensive Component Monitors will log a DTC and switch ON the MIL if a fault is detected in a single Drive Cycle (the exception to this is during a Type A misfire when the MIL will flash).

Chrysler Jeep Two Trip Faults
If the EOBD Monitor detects a fault with one of the Major Emission Monitors during a second successive Drive Cycle, it will log a DTC and switch ON the MIL Lamp.

Ford Falcon Trip Monitor
Ford refer to a DTC logged in the first Drive Cycle as a "Pending DTC".

Ford Falcon First Drive Cycle
If the EOBD Monitor Test detects an emission malfunction during a single Drive Cycle, it will log a Pending DTC but not switch ON the MIL Lamp (the exception to this is during a Type A misfire when the MIL will flash).

Ford Falcon Second Successive Drive Cycle
If the EOBD Monitor Test detects the same emission malfunction during a second successive Drive Cycle, it will log a "Confirmed DTC" and switch ON the MIL Lamp.

Nissan X-Trail Trip Detection
Nissan refer to a "Two Trip Detection Logic" where a DTC that is logged in the first Drive Cycle is a "1st Trip Fault Code".

Nissan X-Trail 1st Trip Fault Code (First Drive Cycle)
If the EOBD Monitor Test detects an emission malfunction during a single Drive Cycle, it will log a "1st Trip Fault Code" and "1st Trip" Freeze Frame Data are stored in the PCM, but not switch ON the MIL Lamp (the exception to this is during a Type A misfire when the MIL will flash).

Nissan X-Trail 2nd Trip Fault Code (Second Successive Drive Cycle)
If the EOBD Monitor Test detects the same emission malfunction during a second successive Drive Cycle, it will log a "2nd Trip Fault Code" in the PCM and switch ON the MIL Lamp.

Nissan X-Trail MIL Lamp Fault

If there is a fault with the MIL Lamp or it's circuit, the PCM cannot warn the driver of a Monitor malfunction. In some situations after repeated MIL Lamp malfunction detection, the PCM may enter fail safe mode (after 5 drive cycles). This limits engine speed by affecting operation of the electronic throttle to warn the driver that there is a fault.

Note!

Failure of the MIL Lamp to operate may provide symptoms of low power due to failsafe mode.

EOBD System Readiness

Different manufacturers use slightly different terminology and variations in communicating System Readiness (all Monitor Tests completed and passed). All EOBD systems will list the various Monitor Readiness status via a compatible Scan Tool.
Some variations are:

Chrysler Jeep Grand Cherokee

Chrysler use the term "**I/M Readiness**" to describe System Readiness status.
Chrysler also use the MIL Lamp to display System Readiness (SRT Status):

1. Switch Ignition ON
2. Wait 15 seconds (the MIL remains ON for this period)
3. If any Monitors are not complete, the MIL will flash for 5 seconds and then remain ON
4. If all Monitors are completed, the MIL will just remain ON while the ignition is switched ON.

Ford BF Falcon P1000 DTC

Ford logs the DTC P1000 to indicate "**System Not Ready**" (one or more Monitor Tests not completed).
The scan tool can also display if any individual Monitors have not been completed.

Nissan X-Trail

Nissan use the term "**System Readiness Test**" (SRT) to describe System Readiness status.
Nissan also use the MIL Lamp to display System Readiness (SRT Status):

1. Switch Ignition ON
2. Wait 20 seconds (the MIL remains ON for this period)
3. If any Monitors are not complete, the MIL will flash for 10 seconds and then remain ON
4. If all Monitors are completed, the MIL will just remain ON while the ignition is switched ON.

Dealer Test Cycle (Readiness Trip)

To assist Technicians in confirming that a Monitor malfunction has been correctly diagnosed and repaired, manufacturers provide a Dealer Drive Cycle that allows Technicians to run all Monitor Tests and confirm System Readiness. The Drive Cycle description varies slightly from one manufacturer to another.

Note!

Before running Dealer Test Cycle, connect scan tool and ensure there are no DTC's logged in the PCM.

Chrysler Jeep Dealer Test Cycle

This requires use of the factory scan tool to guide you through the test cycle. Test is best conducted in this order:

1, Oxygen Sensor Heater Monitor

This requires a cold start where the vehicle has been parked for 8 hours. Coolant must be in 10∟C of ambient temperature and ambient temperature must be between -17∟C and 40∟C. Use the factory scan tool and follow the monitor test procedure.

2, Catalyst Monitor

Vehicle is driven at highway speeds for a few minutes. Use the factory scan tool and follow the monitor test procedure.

3, Oxygen Sensor Monitor

The vehicle needs to be driven for a period of time and then left idling in Drive. Use the factory scan tool and follow the monitor test procedure.

4, Canister Purge Monitor
The Canister Purge Monitor will only run whilst the vehicle is moving in Drive. It requires a closed throttle to occur before commencing. Use the factory scan tool and follow the monitor test procedure.

Ford Falcon Dealer Test Cycle

Each individual Monitor can be run by itself to test that system or repair, but it will not clear the P1000 DTC if other Monitors are not complete.

Notes!

- *Smooth operation of accelerator will assist in Monitor completion.*
- *Test can be conducted on the road or a dynamometer.*
  If the test is carried out on the road, normal road traffic regulations apply.
- *Fuel tank level must be between 20% and 100% level (otherwise the Misfire, Oxygen Sensor, Catalyst and Fuel Monitors are disabled).*

Preparation:
1. Connect Scan Tool to vehicle
2. Switch ignition ON - do not start engine
3. Switch ignition OFF and then and switch ignition ON again
4. Make vehicle selections with Scan Tool
5. Clear Keep Alive Memory (KAM) using Scan Tool
6. Start engine
7. Idle for 15 seconds
8. Drive vehicle at approx 65 km/h to obtain coolant temperature of at least 77∟C (read temperature from scan tool).

Note!

If the ignition is switched Off, the whole cycle needs to start again.

Test Procedure:
Carry out the Dealer Test Cycle in the following order (A -G) :

A. Oxygen Sensor Monitor
1. Accelerate to 68 to 88 km/h
2. Maintain at constant speed in this range for 90 seconds.

B. Catalyst Monitor

1. Drive in stop/start conditions at varied speeds for 5 minutes (including various constant speeds).
2. Drive at constant speed:
   50 km/h in 3rd gear for 3 minutes
   50 km/h on 4th gear for 3 minutes
   50 km/h in 5th gear for 3 minutes (70 km/h in 4th - 4 speed auto)
   95 km/h in 5th gear for 3 minutes (96 km/h in 4th - 4 speed auto)

C. EGR Monitor (DPFE - If Fitted)

1. Accelerate from 0 to 75 km/h with throttle at 75% open
2. Maintain 75 km/h for 25 seconds
3. Stop and idle for 30 seconds
4. Accelerate from 0 to 75 km/h with throttle at 75% open
5. Maintain 75 km/h for 3 minutes
6. Stop and idle for 30 seconds
7. Accelerate from 0 to 95 km/h with throttle at 75% open
8. Maintain 95 km/h for 3 minutes
9. Stop and idle for 30 seconds.

D. Secondary Air Monitor (If Fitted)

- Stop the vehicle and idle for 2 minutes
  i. Manual - Neutral
  ii..Auto Trans - Drive.

E. Comprehensive Component Monitor (Transmission) Manual

- Accelerate moderately from 0 to 80 km/h

F. Auto Transmission

1. Accelerate moderately from 0 to 80 km/h, hold speed for 15 seconds
2. Stop and accelerate moderately to 64 km/h (without using overdrive) and hold speed for 30 seconds.
3. Activate overdrive and accelerate from 64 to 80 km/h and hold for 15 seconds.
4. Stop and idle for 20 seconds
5. Repeat the above 5 times.

G. Misfire and Fuel Monitor
(Profile Correction Learning)

1. Accelerate moderately from 0 to 100 km/h
2. Release accelerator fully, slow to 65 km/h without braking
3. Repeat 3 more times.

Use Scan Tool to confirm all Monitor Tests have been completed.

Note!

If one Monitor has not been completed, repeat the corresponding cycle WITHOUT switching the ignition OFF or clearing the KAM.

Nissan X-Trail Drive Cycle Pattern

This Drive Cycle takes approx. 20 minutes and starts with a cold engine. Coolant temperature must be between -10∟C and 35∟C.
Use a Scan tool to monitor vehicle speed and coolant temperature during this test.

Note!

Ambient temperature should be between 20∟C and 30∟C.
Accelerator must be moved smoothly during acceleration and held steady during steady-state driving.

Preparation:

1. Start engine and idle until coolant temperature is greater than 70_C.
2. Allow to idle for a further 1.5 minutes.

Test Procedure:

Carry out the Dealer Test Cycle in the following order:

1. Accelerate moderately to 90 km/h (takes about 30 seconds)
2. Release the accelerator for at least 10 seconds
3. Accelerate moderately again to 90 km/h
4. Hold a steady speed of 90 km/h for 6.5 minutes
5. Release accelerator and coast to a stop (takes about 30 seconds)
6. Idle stationary for 30 seconds
7. Accelerate moderately again to 90 km/h (takes about 30 seconds)
8. Hold a steady speed of 90 km/h for 1 minute
9. Release accelerator and coast to a stop (takes about 30 seconds)
10. Idle stationary for 60 seconds
11. Accelerate moderately again to 90 km/h (takes about 30 seconds)
12. Hold a steady speed of 90 km/h for 5.5 minutes
13. Release accelerator and coast to a stop (takes about 30 seconds)
14. Switch ignition OFF.

Diagnosis and Testing

Diagnosis is the process of examining the symptoms of a problem or complaint and carefully analysing the facts to determine the cause or causes of the problem or complaint.

Before any tests or testing is carried out the technician will need to have a Diagnostic Plan. Technicians who do not have any Diagnostic Plan or forget to carry out Basic Testing usually end up getting lost, frustrated and annoyed with their diagnosis. This will cause the technician to take a guess as to the vehicle fault, causing components to be replaced that do not need to be replaced.

The overall process of diagnosis and repairing a fault consists of:

- Verification of customer's problem
- Narrowing the problem
- Testing the cause
- Verification of the cause
- Repairing the problem
- Verification of the repair and system operation.

Verify the Problem

The Diagnostic Plan starts when the customer books in the vehicle. We have to get a good understanding of the customer's concern and the symptoms they may be trying to communicate to us. The customer may not have the technical background but has experienced the concern and is trying to explain it to you. Take the time to gather all the information you can. Use the Powertrain Control Diagnostic Worksheet at the back of this book as a guide on information to gather and questions to ask.

Diagnostic Plan Steps

Step 1.
Get detailed information about the fault, the condition and environment in which the incident or symptoms occurred.

Step 2.
Before confirming the concern, record any information that you can to help in pointing you in the correct direction as this can also indicate how much time you spent in your diagnosis.

Step 3.
Keep things simple DO NOT FORGET to carry out Basic Testing first; recording the results.

Key points to elicit are; What, When and Where. **What** is happening, **When** does it happen and **Where** does it happen? Make sure you determine when the problem FIRST started or was first noticed. Sometimes too much information from the customer can either become confusing or not helpful, this will have to be filtered out by the technician on the job. It will be helpful for the technician to take the customer for a road test; having the customer drive initially, so the technician can concentrate looking for the concern.

Note!

In some cases, what the customer is sensing as a problem may actually be a CHARACTERISTIC of that particular model vehicle. Compare to a similar vehicle and demonstrate common characteristic to customer if required.

If the customer concern is not noted correctly it can all get out of shape from there. So the technician may need to start from scratch and take the vehicle for a road test to see what can be found. The important point is to record any information.

Don't forget to check all related systems and functions to confirm WHAT IS WORKING correctly, so you can be sure that you have not created any new problems by the time you have finished.

Note!

Remember to document and record all tests or readings and keep all printouts to support your diagnosis and time taken.

Narrow the Problem
Begin with a visual check of the system and related areas. Don't forget the condition of battery terminals and the battery's state of charge.

Note!

Remember that the fault you are diagnosing may actually be more than one fault.

What You Need for Testing and Diagnosis

information you need:

- Vehicle System Information & Operation
- Wiring Diagrams
- Specifications and Testing Procedures
- Tools and Equipment.

Vehicle and System Information

Having some basic information of the system will give you a head start in at least what components are controlling the system. Most manufactures are now using Serial Data Stream in the form of Bi-Directional Universal Signal (BUS) and protocols as Controlled Area Network (CAN) systems to reduce the number of components. It is critical that the technician looks at the functionality of the system. Knowing how a system is or is not operating gives you an indication where to start looking.

Wiring Diagrams

Having a wiring diagram will give you more than the basic knowledge needed:

- Components used
- Connection between systems and components
- Power supplies
- Ground circuits.

An understanding of the circuit and how the circuit operates must be understood before any testing is carried out.

- Is the circuit fused and if so were are the fuses?
- Is the switching a power or ground side circuit operation?
- Are there any relay(s), resistor(s) within the circuit?
- Do you have an wiring diagram that can help you to become familiar with the circuit?
- Are there any Duty-Cycle signals used?

Fault Codes (or DTC's)
To help narrow the problem, all related systems will need to be checked for Fault Codes (or Diagnostic Trouble Codes - DTC). In most cases this will involve accessing and checking ALL MODULES on the vehicle to determine if there are any related DTC's stored in other any modules. REMEMBER, a DTC by itself is not a diagnosis, it is only a starting point. Some DTC's are indicating a symptom, not the cause.

Reading DTC's

1. Read all DTC's in memory of ALL MODULES - record and then clear these.
2. Switch ignition OFF for at least 10 seconds
3. Run on demand Self Test - record DTC's (confirm faults that currently exist)
4. Run Engine Running Self Test (if applicable) - record DTC's.

If there are numerous DTC's logged, refer to the priority list of DTC's from the workshop manual to determine which ones to tackle first. Some DTC's are not the cause, but are simply a symptom of another fault. The DTC list is found in the AUTO-TECH Encyclopaedia.

Note!
If there is a problem with the PCM grounds, it is likely that multiple DTC's will be logged.

Knowing How To Diagnose
Once you understand how the circuit should work, and have a few "signposts" like DTC's, the next step is to determine where the trouble is likely to be and establish a test point within the circuit (a good starting point would be the power side). Printing the system Voltage Table and recording the tested information next to the correct voltage reading will give an indication as to your next step.

Note!
Always check on the system operation before testing, to know what you should be looking for.

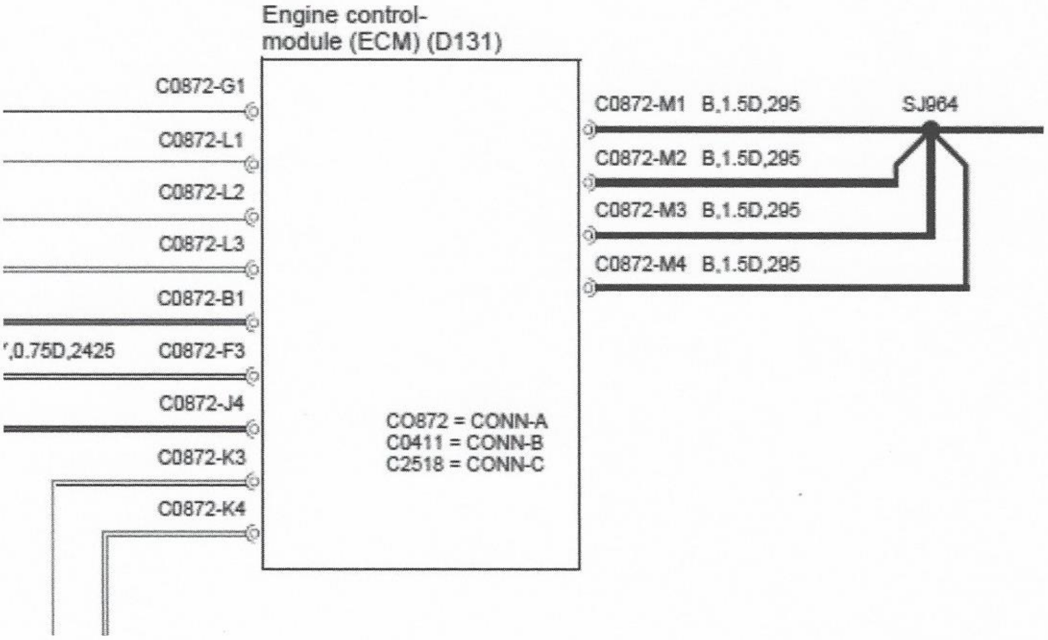
Where possible, don't pass by the opportunity to compare the problem to a "known good" vehicle.

Specifications and Testing Procedures

If you have the specifications for testing the system and components, there is no guess work. The relevant testing procedures can usually be provided by Auto-Tech Tech-Help line.

Typical PCM Voltage Table

Pin #	Circuit	Status	Voltage
G1	Ground	All Times	<0.5 Volts
L1	PCM Power Supply	All Times	Battery Volts
L2	Valve Relay Power Supply	All Times	Battery Volts
L3	Ground - PCM Solenoid	All Times	<0.5 Volts
B1	Wheel Speed Sensor	Ignition ON Wheel Turning	AC Waveform
F3	Diagnostic Connector	Serial Data	N/A
J4	CAN High	Serial Data	N/A


Engine control-
module (ECM) (D131)
C0872-G1
C0872-L1
C0872-L2
C0872-L3
C0872-B1
',0.75D,2425
C0872-F3
C0872-J4
C0872-K3
C0872-K4
C0872-M1 B,1.5D,295
C0872-M2 B,1.5D,295
C0872-M3 B,1.5D,295
C0872-M4 B,1.5D,295
SJ964
CO872 = CONN-A
C0411 = CONN-B
C2518 = CONN-C

Tools and Equipment

This may vary between some systems, particularly with scan tools. A voltage chart will tell you if you can check a circuit with a multimeter or if serial data is involved, a scan tool will probably be needed. Simple testing can still be used to check circuits, but the technician needs to know where to start. Scan tools and Oscilloscopes (Lab Scopes) can be used to make diagnosis easier and some times faster in gathering data.

Note!

As you begin your testing, consider that you may be looking for a single fault OR multiple faults with the system.

Voltage Check

When checking for Voltages, a scan tool can be used to look at system voltages as shown in the Parameter Identification (PID) List, (the PID list is vehicle sensor and Powertrain Control Module inputs and outputs) will give an indication of the voltage that the operating system is seeing. Operating System Voltage is a critical input and is one of the first system checks made in the diagnostic procedure. Control Modules look at the Operation Voltage that is supplied to the Control Module(s) and will make changes on what the Control Module reads. An example is when Supply Voltage drops to the Fuel Injector, the Control Module will compensate by taking appropriate action. If the Voltage Supply drops to the Fuel Injectors, the Control Module will increase the Injector Pulse to allow more fuel flow through the Fuel Injector, so the amount of fuel will remain the same as if the Fuel Injector was operating on the correct voltage.

Whenever checking any system always check that the system you are working on, works the way you are thinking. Some system may work another way or have some variation to its operation or voltages.

Note!

Always check on the system operation before testing, to know what you should be looking for.

Voltage Drop Test

Voltage drop is the direct result of a resistance in a circuit (the higher the resistance, the higher the voltage drop). Using the Society of Automotive Engineers (SAE) standard SAE J541A, the following is the maximum permissible voltage drop.

Maximum Voltage Drop

Description	12 Volt Systems	24 Volt Systems
Small Wire Connections	0.09 Volts	0.09 Volts
Switches	0.3 Volts	0.6 Volts
Solenoid Contacts	0.3 Volts	0.6 Volts
High Current Grounds	0.12 Volts per 100 Amps	0.2 Volts per 100 Amps
Battery Starter Cables	0.15 Volts per 100 Amps	0.4 Volts per 100 Amps

Voltage Drop Test Continued

High current (engine and accessory grounds carrying more than 1 Amp) must be checked for Voltage drop. The starter ground, frequently made through the engine is important for starting. The accessory grounds are important for correct accessory operation (high current must be flowing when the test is made).

Note!

The very low test current used in Ohmmeters can often pass through a high resistance leaving it undetected (it can verify the connection but it cannot verify the QUALITY of the connection). This is why a circuit must be tested under actual operating conditions using a digital Voltmeter capable of measuring hundredths of a Volt (0.00V).

A small resistance can produce a large voltage drop. A resistance of 0.01 Ohms on a circuit carrying 200 Amps is too small to be detected using an Ohmmeter. Ohms Law (E = I X R) shows that this circuit suffers from a voltage drop of 2 Volts (an increase in resistance by a further 0.01 Ohms, gives a total voltage drop of 4 Volts).

Note!

Before replacing any component, check Power and Ground circuits for correct reading.

Verify the Cause

Where possible, verify that you have found the cause. Use a jumper wire around damaged wiring or connector, or fit a test part to confirm that the system will now work as you expect from your diagnosis.

Also where possible, compare the problem to the system on a “known good” vehicle to confirm your findings.

Once you have verified the cause, it is probably safe to advise your customer of your diagnosis and expected costs.

Conduct the Repair

Repair or replace the faulty wiring, connectors or components. Use good quality replacement components and work practices. Your repair must be reliable and restore the vehicle to original condition. Clear all DTC’s from all modules on the vehicle and make note of this. This will help you if there are any ongoing concerns with this vehicle.

Reset all relevant electrical and electronic settings and functions, including:

- Radio PIN, stations and clock
- Idle, closed throttle and other vehicle or system specific relearn functions
- Road test to conduct general relearn functions.

Verify the Repair

Operate the system as you did in the first step. Check that your repair has fixed the fault AND has not created any new problems. Thoroughly test the vehicle and systems and conduct a comprehensive road test. A final Self Test (and clearing of DTC’s if necessary) will ensure that the vehicle is now ready to return to the customer.

Intermittent Faults

It is more difficult to diagnose a fault or system malfunction that occurs intermittently. Most intermittent malfunctions can be caused by poor electric connections or improper wiring.
Where possible, try to simulate the fault environment described by your customer. This may require loading the vehicle up on a dynamometer. If the vehicle is showing no symptoms and the symptoms can not be reproduced, then contintious testing is no longer productive. Try another time when the vehicle is actually playing up.

Mechanical Faults

Don't forget some of the mechanical reasons for some of these system problems. Many modern engines do not use dowels or key ways on flywheels, crankshaft pulleys and sprockets, or camshaft sprockets. Special aligning tools are required to set up the timing on these engines.

Imagine what can occur if the flywheel containing the crankshaft position sensor trigger teeth is removed for repairs and is subsequently refitted in the incorrect position. If it is only slightly out of position, the engine may fire up and run, but will have all sorts of problems. BEFORE removing any of these components, mark the position relative to the crankshaft.

Troubleshooting Considerations

Remember that a DTC by itself is not a diagnosis, it is only a starting point. The following tips don't cover all possibilities, but they may help you identify a problem more quickly.

Oxygen Sensor DTC's

These can be logged if the Oxygen sensor readings remain low (lean) or high (rich), or do not change quickly enough, or do not change at all.

The Oxygen sensor reads unburned oxygen in the exhaust and generates a voltage signal that is proportional to the amount of oxygen in the exhaust. The signal can vary from a low of about 0.1 Volts up to a high of about 0.9 Volts. A low voltage signal indicates a lean fuel mixture. A high voltage signal indicates a rich fuel mixture. The PCM used the Oxygen sensor's input to balance the fuel mixture during closed loop operation. A faulty sensor may prevent the system from going into closed loop and usually causes the fuel mixture to run rich, causing an increase in fuel consumption and emissions.

A low voltage (lean) reading, may indicate a faulty Oxygen sensor, a vacuum leak or a condition that allows unburned oxygen to enter the exhaust. Check intake vacuum at idle and inspect vacuum hose connections. If OK, check for a misfiring cylinder, a burned exhaust valve that is leaking compression or a leaky exhaust manifold gasket.

Oxygen sensor quick checks include watching the sensor's output voltage as the fuel mixture changes. Momentarily disconnecting a vacuum hose will cause a lean response from the Oxygen sensor. No change or a very sluggish response would indicate a faulty sensor.

Note!

If you get an Oxygen sensor DTC plus a random misfire DTC, and a MAP sensor DTC, the engine probably has a serious vacuum leak.

Lean DTC's (P0171 or P0174)

A DTC P0171 or P0174 indicate the engine is running lean. This means there is too much air and/or not enough fuel. You can confirm the engine is running lean by looking at Short Term Fuel Trim (STFT) and Long Term Fuel Trim (LTFT). Normally; STFT and LTFT should be plus or minus 10% to 12% from zero. If STFT and/or LTFT are more than +12% to +15%, it indicates the engine is running lean. Negative numbers (-12% to -15% or more) indicates the engine is running rich.

A lean fuel condition can be caused by:

- Low fuel pressure due to a weak pump or leaky fuel pressure regulator. Use a fuel pressure gauge to check fuel pressure at idle
- Dirty fuel injectors. Try cleaning the injectors
- Vacuum leaks at the intake manifold, vacuum hose connections or throttle body. Use a vacuum gauge to check for low intake vacuum
- Leaky EGR valve
- Leaky PCV valve or hose. Check valve and hose connections
- Dirty or faulty Mass Air Flow sensor (MAF). Try cleaning the MAF sensor wires or filament with an aerosol electronics cleaner. Do NOT use anything else to clean the sensor and do not touch the sensor wires.

Manifold Absolute Pressure (MAP) Sensor DTCs

These can log if the MAP sensor output remains too high or too low (out of normal range), or the MAP sensor readings do not correspond to the Throttle Position Sensor (TPS) readings.
MAP sensors monitor changes in intake vacuum, which is a way of determining engine load. When engine load goes up, intake vacuum drops. Vacuum is highest at idle and deceleration and drops during acceleration and wide open throttle.

The PCM uses the MAP sensor input to vary ignition timing and the fuel mixture. So a MAP sensor fault may cause driveability problems such as surging, poor fuel economy and performance.

MAP sensors either produce a voltage or frequency signal as engine vacuum (load) changes. Vacuum leaks can cause problems with the sensor's reading, so check for leaks and sensor's vacuum connection to the engine. How to check: a MAP sensor's voltage or frequency output should change when engine vacuum (load) changes. If you don't see a change, the sensor is probably faulty and should be replaced. Repeated engine backfiring will damage the MAP sensor.

Throttle Position (TPS) Sensor DTCs

These can be logged if the TPS readings are too high or too low (out of normal range), if the signal is lost or if the signal does not correspond to the MAP sensor's readings.

The TPS sensor monitors the position of the throttle so the PCM can add more fuel when the engine is accelerating or under load. The PCM may also need to know when the throttle is at idle or wide open to control other functions.

A faulty TPS can cause driveability problems such as hesitation. The sensor's resistance changes as the throttle moves, causing the signal voltage to vary. Look for a change in the voltage output as the throttle opens and closes. No change or skips in the output indicates a faulty TPS sensor. Use an oscilloscope to monitor sensor voltage.

On some vehicles, the idle voltage is adjustable on some TPS sensors and must be set within specifications for accurate operation. If the voltage adjustment is not within specifications, it can adversely affect performance and throttle response.

Engine Coolant Temperature Sensor DTCs

These can log if the coolant sensor readings do not change as the engine warms up, if the readings are too high or too low (out of normal range), if there is no signal or if the engine overheats.

The Coolant sensor monitors engine temperature. This is a key function because it allows the fuel management system to go into the closed loop mode of operation when the engine warms up. The PCM also uses engine temperature to control other functions. A failure here can prevent the system from going into closed loop causing a rich fuel mixture and an increase in fuel consumption and emissions.

A coolant sensor's resistance reduces as the temperature increases. If you don't see a change in the resistance as the engine warms up, or the resistance is out of specifications, the sensor is faulty. Other things that can cause faulty sensor reading include a low coolant level in the cooling system, a thermostat that is stuck open or closed, or has an incorrect temperature rating for the engine.

Misfire DTCs

This type of DTC can be logged on EOBD systems if one or more cylinders are misfiring. This can be caused by fouled spark plugs, a weak spark (weak coil), loss of compression, vacuum leaks, anything that causes an unusually lean fuel mixture (lean misfire), an EGR valve that is stuck open, dirty fuel injectors, low fuel pressure or even a dose of bad fuel. A "random misfire" DTC usually indicates a vacuum leak or bad fuel.

If a misfire is only occurring in one or two cylinders, the DTC will tell you which cylinder/s to focus your attention on. Start by removing and inspecting the spark plugs. If oil or carbon fouled, the engine is probably sucking oil past worn valve guides and seals. Replacing the spark plugs will only temporarily solve the misfire problem.

If the spark plug is normal, check the plug lead and boots for damage or looseness. Measure resistance end to end. Replace the lead if resistance exceeds specifications (around 50,000 Ohms per 300mm).

Next, check compression. If low, the cylinder may have a burned exhaust valve or leaky head gasket.

Note!

Carbon under the inlet or exhaust valve will also cause no compression.

If ignition and compression are both OK, focus next on the injectors. Use a test light or Voltmeter to see if the injector is receiving voltage when the ignition is ON and that the injector solenoid clicks when the injector circuit is grounded. If the injector is functioning electrically, it may be clogged with fuel deposits. If cleaning cannot restore normal fuel delivery, the injector must be replaced.

Misfire in two "paired" cylinders in an engine that has a distributorless ignition system (DIS) would usually tell you the DIS system has a faulty coil. If each cylinder has its own coil, only one cylinder will be affected.

EGR Related DTCs

These DTC's can log if the EGR valve is not opening, or is not flowing enough exhaust gas to keep oxides of nitrogen (NOx) emissions under control.

The EGR system routes a small amount of exhaust back into the intake manifold when the engine is lightly loaded to prevent combustion temperatures going too high. This keeps the formation of NOx to a minimum. If the valve fails to open, the engine will usually experience detonation (spark knock or ping) under load. If the valve is stuck open, it will create a vacuum leak causing idle roughness, hesitation and lean misfire.

If the valve can be visually inspected, look for movement in the valve stem as the engine is revved (it may be necessary to partially restrict the tailpipe to create sufficient back pressure for this to occur on some vehicles).
Applying vacuum directly to the EGR valve itself should also cause it to open, causing a noticeable change in idle quality. No change usually indicates a faulty or clogged EGR valve.

If the EGR valve itself is working, check to see that the vacuum hose connection is properly routed and is not leaking. Also, check any solenoids in the line for proper operation.

Electronic EGR valves use one or more solenoids to open the valve. These can be tested by applying voltage to the solenoid terminals. No movement would indicate a faulty valve.
EGR valve passageways in the manifold are often found to be blocked with carbon deposits. Remove the valve and inspect for deposits.

Crankshaft Position Sensor & Ignition Reference DTCs

These can log if the PCM fails to see the proper timing signal from a Crankshaft sensor, Camshaft sensor or distributor pick up.
The PCM needs a timing signal for ignition timing and fuel injector timing. No timing signal will prevent the engine from starting.

A quick check is to see if the engine generates a spark when it is being cranked. No spark typically indicates no pick up timing signal, a faulty coil or ignition module.

Check for a Crankshaft sensor output signal when the engine is being cranked. Hall effect sensors will create an On-Off voltage signal. Problems with this type of sensor include loss of the 5 Volt reference signal from the PCM. They need a supply voltage to produce an output signal.

Crankshaft Position Sensor & Ignition Reference DTCs Continued

Magnetic Crankshaft Position sensors produce an alternating current (AC) signal. Problems here include loose or broken wires, metallic debris on the sensor tip or the sensor tip is too far away from the machined notches or reluctor wheel. If a magnetic sensor's resistance is out of specifications, it is faulty and needs to be replaced.

How Engine Conditions Effect Petrol Engine Emissions

	HC	CO	CO_2	O2	NOx
Ignition Misfire	Very High	Lower	Lower	Much Higher	Much Lower
Compression Loss	Very High	Lower	Lower	Higher	Much Lower
Rich Mixture	Higher	Very High	Lower	Lower	Much Lower
Lean Mixture	Higher	Much Lower	Lower	Higher	Much Lower
Very Lean Mixture	Very High	Very Low	Lower	Very High	Higher
Slightly Retarded Timing	Lower	No Change	No Change	No Change	Much Lower
Very Retarded Timing	Higher	No Change	Much Lower	No Change	Higher
Advanced Timing	Higher	No Change	No Change	No Change	Much Higher
EGR Operating	No Change	No Change	Lower	No Change	Much Lower
EGR Leaking	Higher	No Change	No Change	No Change	No Change
AIR System Defective	Higher	Higher	Lower	Much Lower	No Change
Cat Converter Dead	Higher	Higher	Lower	Higher	Higher
Exhaust Leak	Lower	Lower	Lower	Higher	No Change
Worn Rings/Valve Guides	Higher	Higher	Lower	Lower	No Change
Flat Camshaft Lobe	No Change	No Change	Lower	No Change	

Serial Data Stream

Serial Data may be bi-directional or single direction and enables the passage of rapidly changing electronic voltage signals, pulsed high and low volts, to communicate operating information from sensors and actuators to other electronic modules. BUS communication is used to communicate with other modules (computers).

Note!

Serial Data Communication, is known as BUS Communication (Bi-Directional Universal Signal).

Early Vehicle Networks

The earliest vehicle network systems used a central module to control the communication network. The controlling module was like a communication centre. The main controlling module would request or send information to other modules, eg. Powertrain Control Module (PCM), Electronic Climate Control (ECC), Instrument Cluster, Anti Lock Brakes/Electronic Traction Control System (ABS/ETC), via the BUS line (also known as polling). The data provided by each module may be used by any module connected to the BUS line. Each module has a unique response (Message Identifier Word or MIW) for identification. The controlling module surveys each module for a status update.

Controller Area Network (CAN)

Many newer vehicles are using CAN networks. CAN is required to meet OBDII requirements from the 2008 model year. With a CAN network, each module acts as an independent supplier and consumer of information that is broadcast onto a network.

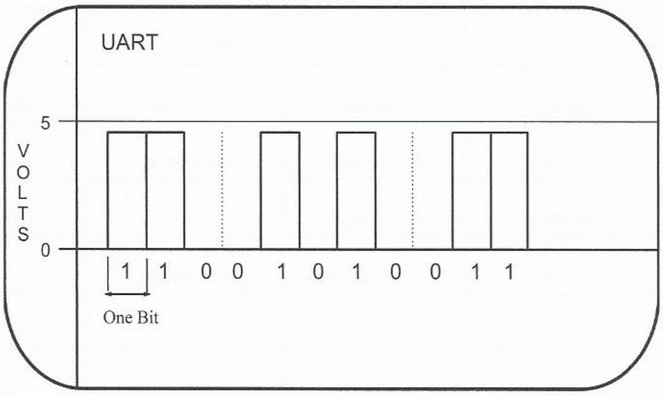
Serial data (Data Stream) from the BUS line can be read by scan tools and information can be obtained from various modules for diagnosing malfunctions or verifying circuit status.

Note!

Taking voltage readings on a network does not provide the Technician with any useful data information. It simply confirms that part or all of the circuit is probably still connected if voltage levels are "normal".

Baud Rate

A serial data stream contains bits (Binary Digits) representing coded information and each bit holds a specific place in the data stream. Bits can represent a message being sent or a separation between messages. These bits are being sent at precise time intervals. The speed at which bits are transmitted is called the Baud Rate.



Serial Data Digital Waveform

Note!

Some Scan Tools cannot be used on certain vehicle computer systems because of the different Baud Rate used.

Manufacturer Networks & Protocols

The meaning of the word Protocol in the English Dictionary is: "rules of behaviour". Over the years, each manufacturer has developed their own rules of behaviour for data communication. Another way of thinking of protocols is each is like different languages. This means that not all protocols will send or read information in the same way, just like different languages are not structured the same way and cannot be understood by all.

The information is communicated in an order which is determined by the protocol used. The communication may start and end with a unique pulse to identify different information communicated in the data stream. Manufacturers may use different communication network systems to communicate with other network systems within the vehicle.

Manufacturers use communication networks similar to PC's. Some examples that have been in use are:

- Universal Asynchronous Receiver Transmitter (UART) - GM
- Standard Corporate Protocol (SCP) - Ford
- Audio Corporate Protocol (ACP) - Ford

Modules must speak the same language in order to communicate with each other. The protocol in the different networks may not speak the same language. An example is the Ford Taurus system on the previous pages.

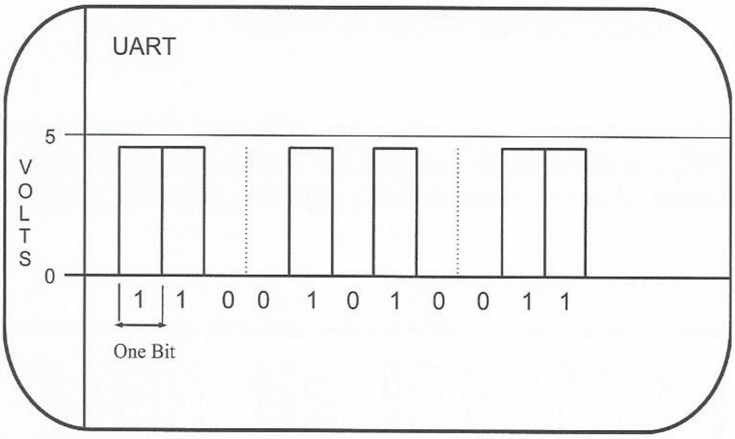
The ACP network is linked to the SCP network through the A/C Climate Control Module (A/C CCM), data information in the A/C CCM is unable to communicate across to the SCP network. The two protocols are linked because the A/C CCM must receive operating information from the SCP network.

This also means that there are three separate diagnostic procedures for:
- A/C CCM network - tested manually at the A/C CCM
- SCP linked modules
- ISO linked modules

The last two networks will be invisible to the Technician as they are accessed using a scan tool.

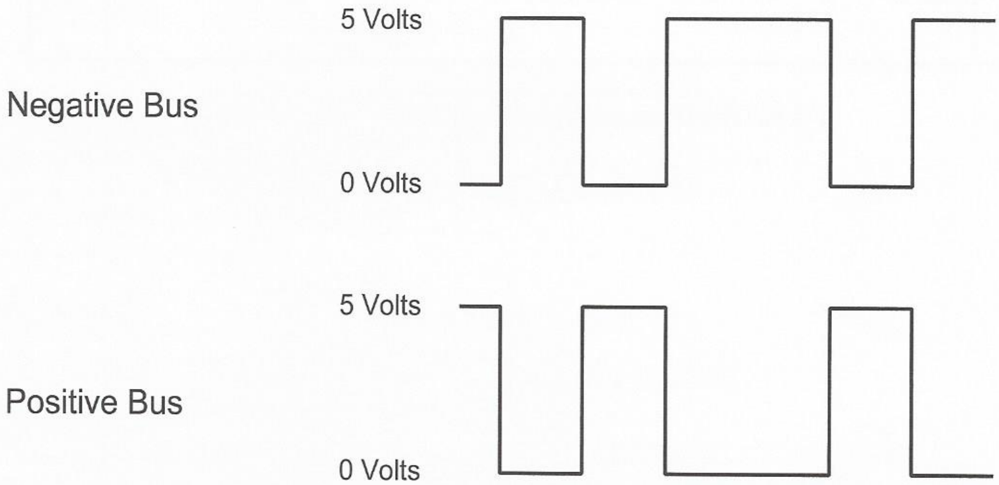
UART Network

Universal Asynchronous Receiver and Transmitter (UART) uses a fixed pulse width wave on a single wire. It is pulsed from 0v (Low) and to 5v (High) and uses a fixed Bit pulse width.



Serial Data Digital Waveform

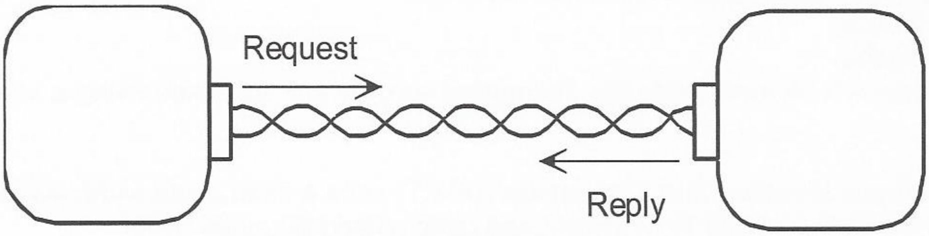
Each digital signal is called a Bit and represents a number. The computer puts these Bits together to make a Word. Eight Bits make a Word and a typical serial data stream may have up to 64 Words. As an example, some systems transmit data at a rate of 8.2 kilobits per second (8,200 bits).



Serial Data Example

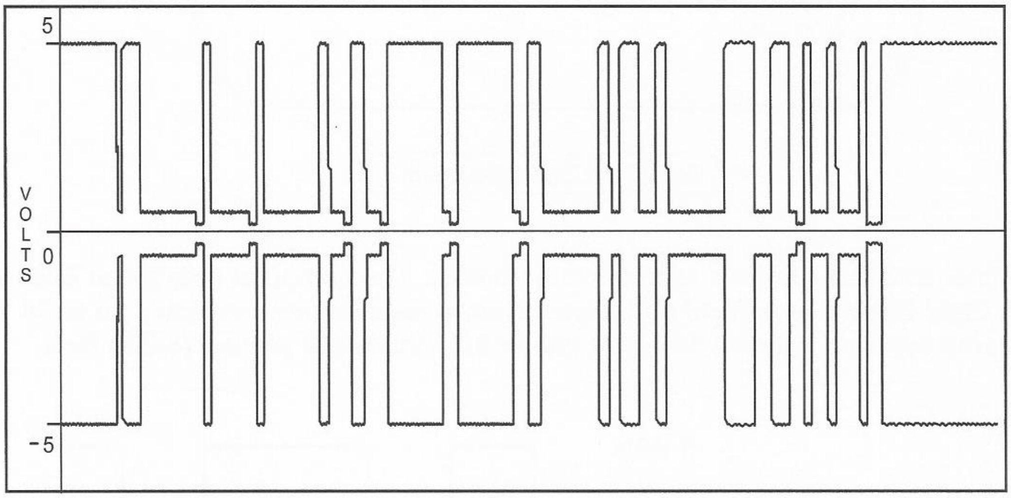
Ford SCP Network

Ford Standard Corporate Protocol (SCP) is a communication data stream that is transmitted through two wires known as a twisted pair. It meets the SAE J1850 standard. The SCP is pulsed from 0v (Low) and to 5v (High). This method takes advantage of the differential noise capacity of a twisted pair, minimising the effects of external electrical interference on the system.



Intermodule Communication

A mirror reversed signal is sent across these two wires. When no transferring of information is taking place, the BUS+ is held High and the BUS- is held Low. When pulses of information are transferred, identical data is sent on each of these wires but with opposite potential. Data is transferred at 41.6 Kilobits per second.



5 Volt Bus Commmunication (Dual Wire)

Industry Standard Networks & Protocols

In recent years there has been some industry standardisation of protocols.

- For diagnosis, the single wire ISO 9141-2 network and protocol has been used for some time.
- For real time operating data sharing, the Bosch licensed Controller Area Network (CAN) network and protocol is used.

A modern vehicle may use both these protocols for system operation and diagnosis.

SAE Standards

To classify the various standards, the SAE (Society of Automotive Engineers) has defined the basic categories on in-vehicle networks based on network speed and functions:

Class A

Low speed (<10K bits/ second)
Convenience features (entertainment, audio, trip computer etc.)

Class B

Medium speed (10k bits/sec to 125 k bits/sec)
General information transfer (instrument cluster, vehicle speed, emission data etc.)

Class C

High speed (125K bits/sec to 1M bits/sec or greater)
Real time control (powertrain control, vehicle dynamics etc.).

A high speed CAN (Class C) network can be compared to commuting to work at 320 kph versus 10 kph for a Class B protocol. The travel time is much less for the Class C network. This travel time; known as latency, is critical for safety and real time control of a vehicle system, because any delays in communication could be disastrous (causing anything from an engine stall to a vehicle crash).

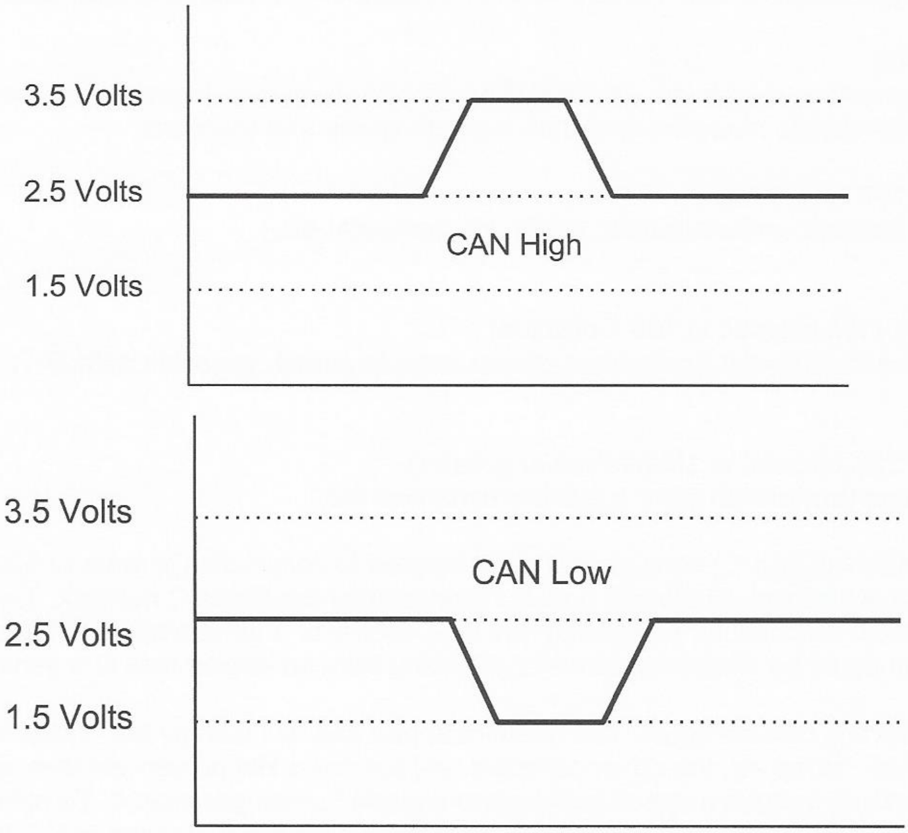
Not all networks are created equal. The need for speed and low latency are critical for powertrain and vehicle dynamics. However, the driver compartment functions like power windows and instrumentation only require a speed sufficient to exceed human perception. To optimise the costs and control data access, multiple networks in a single vehicle are becoming common. For example, a CAN network running at 500 kbits/sec may link the engine, transmission and ABS, while a slower CAN network could link the doors, instrumentation and other body electronics.

International Standards Organisation Protocol Network ISO 9141-2 (Standard Number 9141-2)

Data transmitted on the ISO serial line is transmitted according to a code governed by the International Standards Organisation. The ISO network transfers information at a rate of 10.4 kilobits per second and a message will take around 9 milliseconds to transfer.
The ISO network uses a single wire and it pulses from 0 volts (Low) to 10 volts (High). An ISO network is used for diagnostic purposes only. There is no communication between individual modules on the ISO line network. The ISO network is often identified as the "K Line" and is connected to diagnostic connector terminal #7.

Controller Area Network (CAN)

The CAN Network provides serial data for real time powertrain, ABS and vehicle dynamics etc. All modules are connected in parallel via two communication lines called CAN L (CAN Low) and CAN H (CAN High) on a Bi-directional Universal Signal (BUS) line. Each end of the main bus line CAN L and CAN H are joined with an “end resistance”.


3.5 Volts
2.5 Volts
CAN High
1.5 Volts
3.5 Volts
CAN Low
2.5 Volts
1.5 Volts

CAN Differential Voltage Signals

Controller Area Network (CAN)

Each module on the BUS is a "node" and sends and receives messages. The "terminating nodes" are usually located in two key modules, such as the PCM and Instrument Cluster. The terminating nodes contain 120 Ohm resistors across each Bus wire to prevent corruption of the high speed signals. If there is a break in the network, some modules may not be able to communicate with each other.

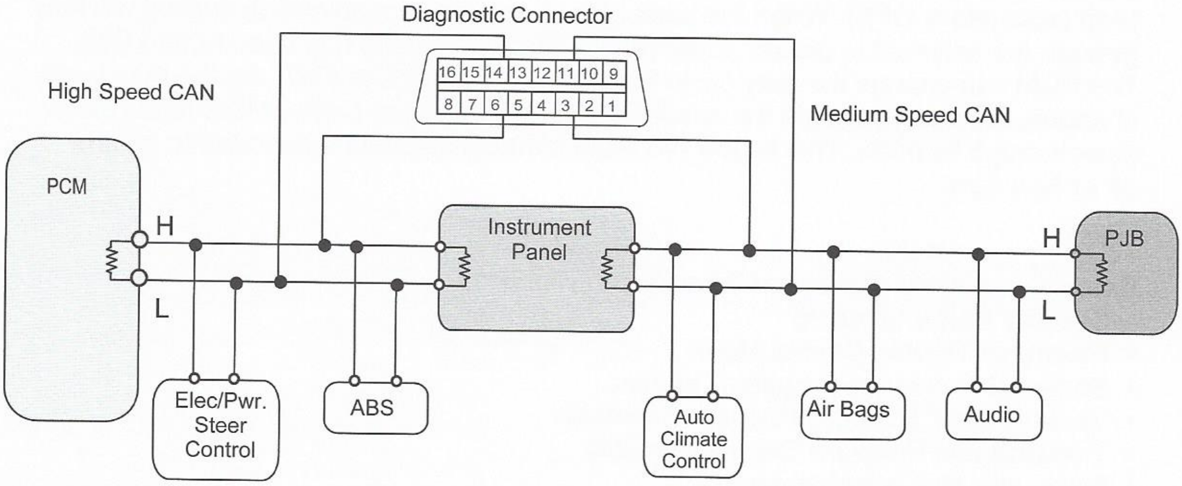
Mazda 3 CAN BUS Network

The Mazda 3 has two separate CAN BUS networks.

- High Speed BUS is used for all critical vehicle functions
- Medium Speed BUS is used for all non critical functions.

Data can be shared across the two BUS networks via the instrument cluster (Powertrain information is required by the Climate Control System).

CAN BUS wiring (connecting all modules together) is a twisted pair of wires that receive 35 to 55 twists per metre to reduce interference. A differential voltage, operating between 1.5 and 3.5 volts is used. Idle state voltage on both wires is 2.5 volts approx.The High Speed CAN BUS network is connected to diagnostic connector terminals #6 and 14.


Diagnostic Connector
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
High Speed CAN
Medium Speed CAN
PCM
H
L
Instrument Panel
H
L
PJB
Elec/Pwr. Steer Control
ABS
Auto Climate Control
Air Bags
Audio

CAN Networks Mazda 3

Note!

When the ignition is switched OFF, a module such as the Body Control Module (BCM) may continue to communicate with other modules.
This allows for communication and external control of the BUS prior to the ignition being switched back ON.

Pulse Width Modulation (PWM)

To be able to have better management of solenoids and be able to control the forces acting on the solenoid actuators, a Pulse Width Modulation signal is used. This signal uses a constant frequency and a changing duty cycle.

Frequency

Frequency is how many times the voltage turns ON and OFF in a period of time. The time span is one second and is called Hertz (cycles per second). A frequency of 32 Hz means a voltage is pulsed ON and OFF 32 times in one second.

Duty cycle

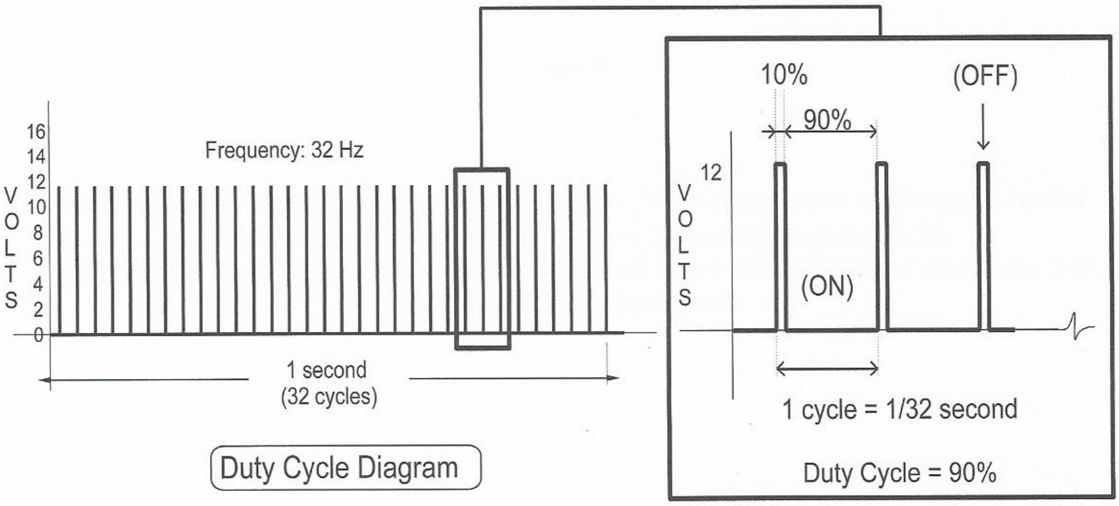
Duty cycle is what happened in just one of the ON-OFF signals. If we have a duty cycle of 70%, the ON time is 70% of the pulse time and OFF for 30% of the time. This is called a 70% negative duty cycle (negative meaning the ON time equals low volts, positive meaning the OFF time equals low volts).

In many applications the solenoid is constantly fed 12 volts from a fused power supply and is controlled (switched ON and OFF) by a transistor in the PCM providing a ground. When the transistor is not providing the ground, the voltage on the circuit is High (solenoid is OFF). When the computer closes the ground circuit, current will flow through the solenoid to ground (Low voltage state - solenoid has been turned ON). The PCM can change the duty cycle from 0% (OFF) to 100% (ON). As the duty cycle changes, the plunger inside the solenoid will move allowing more or less fluid / air to pass through its ports. This is how the PCM controls solenoid movement to control air or fluid flow.

Note!

Examples of PWM Controlled Devices:

- Canister Purge Solenoid
- Electronic Throttle Control Motor
- Some EGR Vacuum Regulator Valves
- Variable Cam Timing Oil Control Solenoids
- Transmission Pressure Control Solenoid
- Some Idle Air Control Motor.



Duty Cycle Diagram

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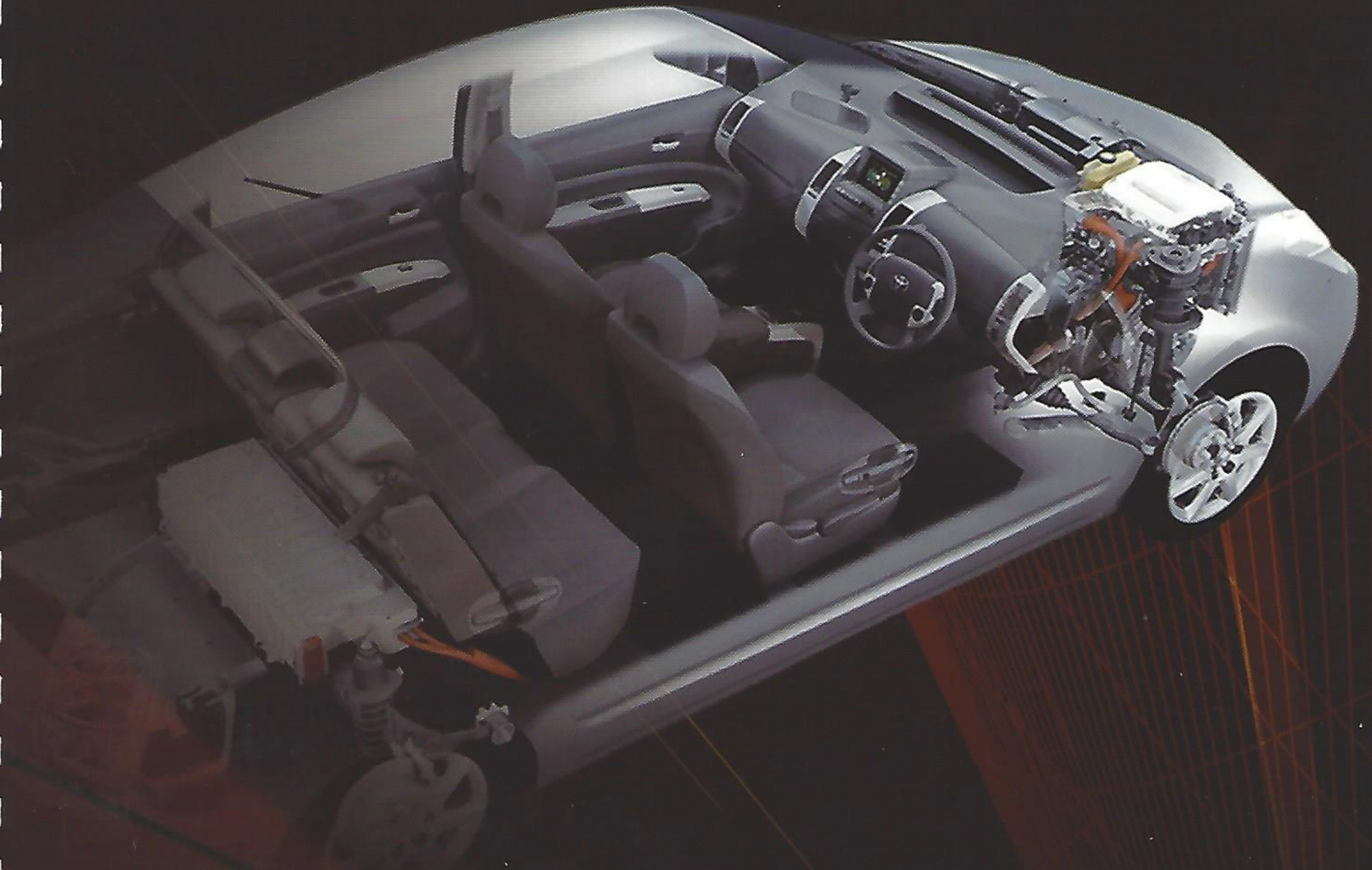

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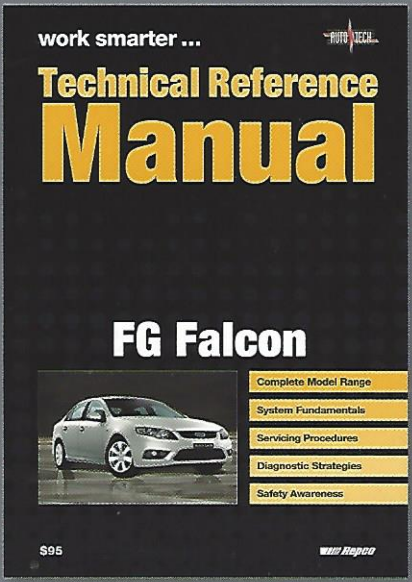

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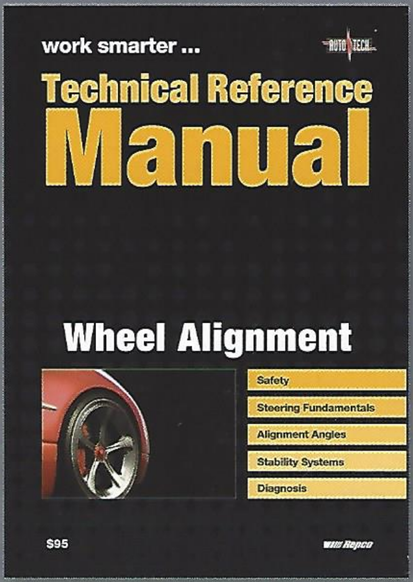

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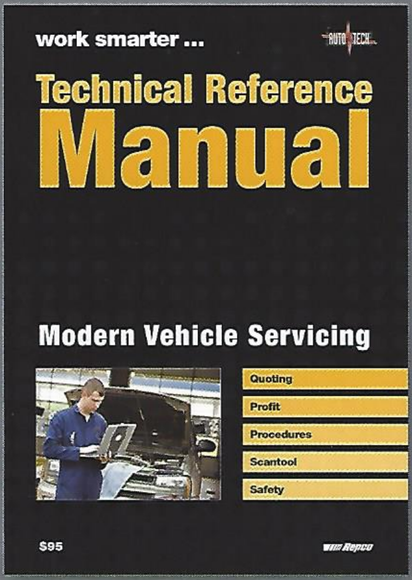

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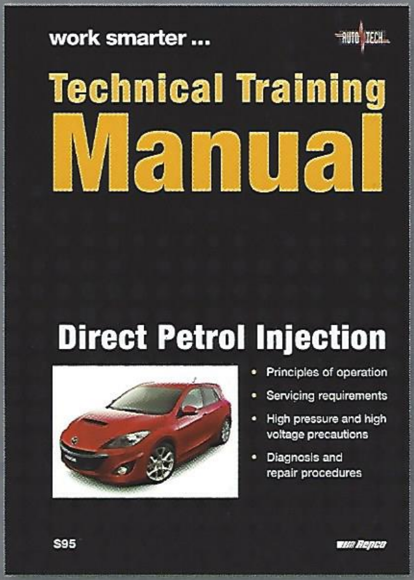

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